Final Report

VAST - Voice Assisted Sewing Technology

April 1995

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SOW #33: Problem Solving for Apparel Manufacturers
Speech Recognition Systems for Apparel Device Control

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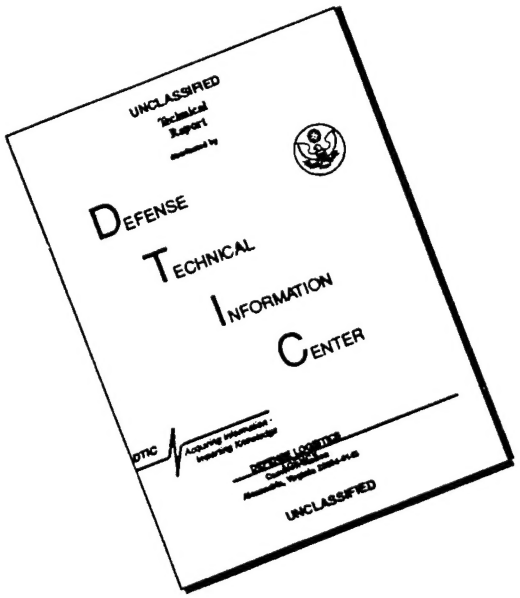

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SOW #33: Problem Solving for Apparel Manufacturers Speech Recognition Systems for Apparel Device Control

Dr. John C. Peck

Background

The focus of this research project was the development, testing and evaluation of a portable computer that uses speech recognition technology to control the operation of a sewing machine or similar device.

Motivation for this research comes from two primary application areas, ergonomics and employment opportunities for the physically challenged. Modular manufacturing is becoming increasingly popular in the apparel industry. This type of team sewing is usually organized to reduce bottlenecks in product flow by often movement of participants to different operations. Most modular manufacturing teams stand while sewing in order to reduce the time required to travel between operations. Since most sewing devices still use a foot pedal to activate and control operations, most of an operator's weight is placed on the other leg. Over an extended period of time, excess weight on this leg can cause pain and lead to work related injuries. In summary, the ergonomics of this type of sewing posture is extremely poor and can be improved through use of the VAST device.

Creation of opportunities for the physically challenged in manufacturing has been a goal for many years. Since most sewing devices require the use of an operator's hands to guide fabric under the sewing needle, a foot pedal is normally used to control the actions of the machine. Unfortunately, a foot pedal cannot be used by many handicapped persons who have no control over their legs but have excellent control over their hands, arms and upper body parts. In summary, the physically challenged can benefit greatly from use of the VAST device by enabling them to gain employment in the apparel industry.

Initial work on this project was funded by EFKA of America and was exhibited at the 1991 Bobbin Show. Through the resources provided by this contract the project has technically matured to the point where it is now being offered for sale as a valuable work aid.

Report Organization

This report is organized by task as found in the original proposal. A functional description of the VAST device can be found in the User Manual in Appendix A while a technical description can be found in the Patent Application in Appendix B.

Task 1 - Improve PC Interface Software

The PC software for down-loading and up-loading was re-written to become more user friendly. In particular, the "jargon" was changed from the language of a computer programmer to the language common to apparel manufacturing. A complete User Manual describing the software and its operation is found in Appendix A.

Task 2 - Evaluate Alternative Microphones

Several microphones were tested and evaluated in light of the intended application. The three primary categories of microphones used were boom mikes, throat mikes and ear mikes. The relative advantages of each category is found in the following table:

Category	Rating (1-10)	Advantages/Disadvantages
Boom	8	Advantages: - Good frequency range for speech - Comfortable Disadvantages: - Subject to external noise interference
Throat	5	Advantages: - Immune to external noise interference Disadvantages: - Does not pick up high frequencies - Uncomfortable - Position on neck is critical
Ear	1	Advantages: - Immune to external noise interference Disadvantages: - Does not pick up high frequencies - Rubbing inside ear causes interference - Uncomfortable - Insufficient volume

In general, the boom microphones proved to be the best choice for most applications. Careful setting of the gain parameter at the sewing station can be used to accept the user speech signals and yet reject the external noise generated from the sewing machine. Algorithms developed to subtract out the constant background noise

(noise cancellation) have proved effective and enhance the performance of the boom microphone.

The throat microphone was found to be necessary in only the most harsh working environment. In particular, when used to control a riveting machine that generated a random "bang" sound, the throat mike was superior to all other microphones.

In no case was the ear microphone found to perform better than the other microphones.

The microphones tested by brand name and model were:

Manufacturer	Type	Model	Rating (1-10)
Realistic	Ear	TRC-504	1
Racal Acoustics	Throat	Secrette Headset	5
Shure	Boom	SM10A	6
Telex	Boom	PH-1	8
Telex	Boom	PH-62	7
Telex	Boom	PH-8	7
Audio-technica	Boom	Pro Series	8

Task 3 - Field Testing

Field testing was conducted at five locations:

- Levi Strauss - Blue Ridge, GA
- Levi Strauss - Harris, AK
- DPSC, Philadelphia, PA
- Wieland Designs, Goshen, IN
- Clemson Apparel Research - Clemson, SC

The results of this testing was not as satisfactory as hoped due to a variety of conditions outside the scope project control. The results of these tests are summarized below.

Levi Strauss - Blue Ridge, GA

The system was installed successfully to control a sewing machine used in a stand-up operation sewing jeans. The operator of the machine used a throat

microphone due to the extremely noisy operation of the sewing machine. As expected, the initial operation of VAST resulted in a reduced performance efficiency than the foot pedal. Plans were to continue using VAST and measure the increase in productivity over time. Unfortunately, due to severe demands for productivity performance, the test was prematurely terminated and no adequate data was collected.

Levi Strauss - Harris, AK

The VAST units used in the Blue Ridge, GA test were shipped to Somewhere, AK to be attached to a start/stop machine used to staple instruction cards to the back pocket of jeans. Modifications to the VAST unit to interface to this new machine were made and tested in Arkansas. The throat microphone was again used due to the loud operation of the staple machine. The machine operation was observed for 4 hours before leaving further testing to the plant personnel. Unfortunately, due to severe demands for productivity performance, the test was prematurely terminated and no adequate data was collected.

Defense Personnel Support Center, Philadelphia, PA

Two VAST units were installed in the Defense Personnel Support Center factory in Philadelphia, PA. A physically challenged operator was interviewed and hired to operate a sewing machine using VAST. Initial tests, using the throat microphone, were positive and the operator was successfully performing sewing tasks; however, after a few months, the operator quit the job and subsequently, the DPSC factory closed. Again, no meaningful data was collected to adequately measure performance.

Wieland Designs, Goshen, IN

Wieland Designs manufactures conversion van seats. Due to the large size of the panels being sewn, many of the operations require stand-up sewing. Two visits were made to install and test the new and improved VAST unit at Wieland. Initial tests were performed with a boom microphone, and after tuning external noise out with the gain control, the units performed remarkably well, with about .5 errors per usage hour. With extended use, this number was expected to decrease. In spite of the success in operation, the sewing operator decided to abandon the test because of reduced performance. Management paid all operators a fixed hourly rate, but the operator insisted that she could not tolerate the reduced productivity and asked to be removed from the testing. Management then selected another employee for the test and that employee produced similar results in errors. At last report, the unit was still in production at Wieland.

Clemson Apparel Research - Clemson, SC

Clemson Apparel Research hired a disabled Vietnam Veteran to use the VAST system for production work. The person hired had no previous sewing experience but picked up the basics very quickly. The boom microphone was used exclusively and results were very positive. Recognition accuracy was better than 99% with Type I errors (not recognizing the correct word) and essentially 100% with Type II errors (recognizing the wrong word). Performance over time was considered about average for the jobs performed. Unfortunately, the disabled employee resigned from CAR because his disability benefits, when not working, exceeded the pay offered by the State of South Carolina, through CAR.

Task 4 - Develop Radio Frequency (RF) Interface

An RF interface was developed to enable the VAST unit to function in a truly portable mode and access information via voice commands. Intermec Corporation donated a piece of RF equipment, called a tracker, necessary to adapt VAST to this application. In laboratory tests and at the 1993 Bobbin Show, voice commands were used to send data through radio signals to an RF base station connected to a PC. The PC then accessed data on a file and transmitted a response via the RF unit to the VAST device, which in turn synthesized speech corresponding to the response. The input/output port on the VAST unit used for this purpose was the serial port. A possible application for this technology is to assist case handling personnel in distribution centers determine the location of a product to be retrieved or placed. The name of the product could be used as a verbal command, or a bar-code could be scanned. In either case the information retrieved from a database of product locations could be used to inform the operator about the location to which the product should be carried.

Task 5 - Investigate Engineering Improvements

A number of engineering improvements were investigated, implemented and tested to give the VAST unit more functionality and a more user-friendly operational interface. Specifically these improvements were:

- to reduce the circuitry from multiple printed circuit boards to a single circuit board
- to include an internal Ni-Cad batteries for truly portable operation
- include an infra-red transmitter to communicate with the interface box without cables
- to include an auto-gain feature that optimizes the speech signal-to-noise ratio

- to include a button to enable an automatic train session without connection to a PC
- to include a digitized (human) speech capability for a specified vocabulary
- to reduce the cost of the unit to approximately 1/2 of the original cost

The current VAST unit is the third generation of this product and includes all the features listed above as well as the features in the original unit.

Task 6 - Develop Licensing, Manufacturing and Marketing Plans

A licensing agreement was developed and is included in Appendix C. This agreement was signed with EFKA of America on September 11, 1992 and EFKA began marketing shortly thereafter. Unfortunately, EFKA's marketing program proved insufficient to provide widespread coverage of the market with the VAST unit. On February 8, 1994 EFKA terminated the contract. Clemson University has now contacted several other potential marketing agents and is also pursuing marketing on its own.

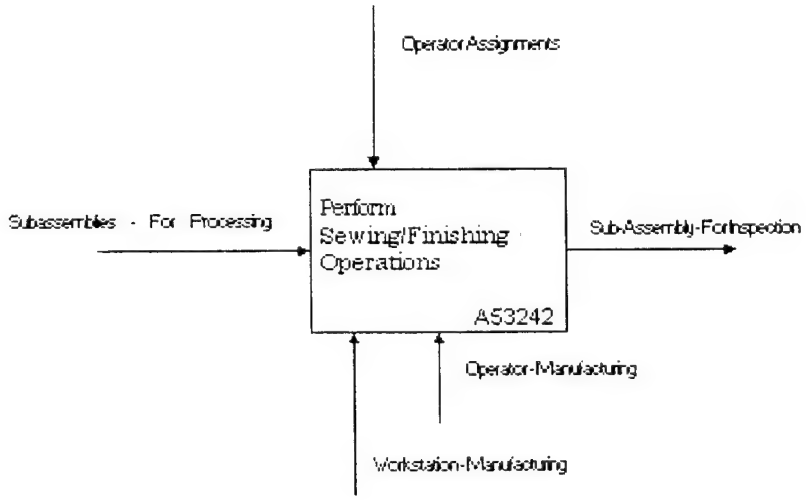
A manufacturing agreement has been constructed with the Voice Connection in Irvine, California. This company is the sole distributor of the AS16 IC chip used to filter the spoken words and manufactures other speech related products for a number of applications.

Task 7 - Incorporate AMA into Project

The VAST project in included in the AMA developed by Georgia Tech in the node numbered A53243. The structure of this node of the IDEF0 model is:

Task 8 - Produce Monthly Progress Reports

Monthly reports were filed in accordance to the terms of the contract.



Task 9 - Report on Research Results

This document represents the final report on the research project.

Appendix A

Functional Description

User Manual

VAST

Voice Assisted Sewing Technology

User Manual

March 1995

Clemson Apparel Research
Clemson University

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INTRODUCTION

The VAST (Voice Activated Sewing Technology) product is a speech recognition based device that controls machines designed to sew, rivet, staple or perform other similar operations. Since most sewing devices require the use of an operator's hands to guide the fabric under the sewing needle, a foot pedal is normally used to control the actions of the machine. The VAST system provides an alternate method to control a sewing machine driven by a digital controlled electric motor.

The VAST system consists of a small portable computer and microphone worn by an operator who speaks commands to the sewing machine. The computer matches each command spoken with a list of voice reference patterns for commands recorded earlier. Once the computer recognizes the command, an electronic signal is transmitted to the digital motor controller through an interface to initiate an action like sew slow, medium, fast, stop, raise, trim etc.

The entire VAST system consists of the following hardware:

1. The VAST unit, a small portable computer worn by the operator.
2. An interface control box that receives signals from the VAST unit and in turn converts them to signals sent to the sewing machine motor. These signals can be received via an infrared receiver on the interface box or can be received via a cable connecting the VAST unit to the interface box.
3. A cable that connects the portable computer to a PC.
4. A microphone worn by the operator and connected to the computer.
5. A power supply for the interface control box.
6. A power supply for recharging the computer's internal NiCad battery.

The system also consists of software available on a diskette. The software must be used on an IBM compatible PC running DOS, provided by the customer.

FUNDAMENTAL CONCEPTS

The first task in using the VAST unit is to decide which words are to be used to control the sewing machine and which actions are to be taken by the machine as a result of recognizing those words. The words and the actions are entered into an IBM compatible PC through use of a computer program provided with VAST. The words, actions to be taken upon recognition and next subvocabulary are collectively called a **vocabulary table** and are stored on the disk of the PC for later use. The vocabulary may be divided into **subvocabularies**, each with a collection of words to be recognized. The start and end of each vocabulary are delimited by

subvocabulary names in parentheses. Using the software provided, the user may **train** the VAST unit to recognize the words by supplying a sample of the user's voice saying each word. This sample is provided by the user speaking each word in the vocabulary in response to a verbal prompt from the VAST box to the user through a speaker in the VAST unit or by a headset earphone worn by the user.

When using the VAST unit in production, the user speaks a word into the microphone and the VAST unit attempts to match the spoken word against the list of word samples collected earlier during training. If a match is found, the VAST unit takes the action specified in the vocabulary table and then transfers recognition control to the subvocabulary specified in the table (if one is specified). Recognition of subsequent words is restricted to the subvocabulary to which transfer was made. The restriction of recognition improves recognition accuracy as well as recognition performance time.

SOFTWARE INSTALLATION PROCEDURE

In order to install the software on the PC the following steps must be executed:

1. Insert the diskette into any available drive.

2. If the diskette is in drive A type "a:" and press the enter key. If in drive B type "b:" and press the enter key.

3. At the prompt type "install" and press the enter key. From now on follow the directions on the screen.

VAST OPERATION OVERVIEW

The steps to using the VAST unit are:

1. Use a PC to create a vocabulary for VAST to recognize and take actions.

    a. Create a new vocabulary or modify an existing one to identify words for recognition and actions to be taken after recognition.

    b. Compile the vocabulary to an internal format.

    c. Connect VAST to the PC through the serial port of the PC.

d. Download the vocabulary to the VAST unit.

2. Use a PC to collect a sample of the speaker's voice (train the VAST unit) speaking each word in the vocabulary several times.

   a. Optionally upload the voice reference patterns to the PC for long-term storage on disk.

   b. Set any parameters in the VAST unit according to the speaker, microphone type and environment.

   c. Verify the recognition accuracy of the VAST unit with the PC before use.

3. Connect the VAST unit to a sewing device and speak words to activate appropriate actions as specified by the vocabulary.

   a. Disconnected the VAST unit from the PC and connect to the interface control box.

   b. Set the switch on the control box to the OFF position.

   c. Verify that the control box is connected to the motor of the sewing device.

   d. Speak the word "STOP" to place the control box (and thus the sewing machine) in a known state.

   e. Flip the switch on the control box to the ON position and begin use.

HARDWARE OPERATION

Specifications

NEC V25 processor operating at
- System RAM (standard 32K and expandable to 256K)
- System ROM
- AS16 filters
- Speech synthesis
- Digital recorded speech
- Volume control
- Training button
- Update button
- NiCad rechargeable batteries
- Parallel port
- Infrared transmitter port
- Serial port
- 9-pin serial cable to connect the VAST unit to a PC

9V AC adapter

Microphones
- Boom mike - Used in environments without excessive noise.
- Throat mike - Used in high noise environments

Interface box
- Infrared receiver port
- 9V AC adapter
- cable to plug into the sewing machine motor and replace the foot pedal

Parallel Port Operation

The parallel port is used to latch control signals on 8 output lines controlled by software. The lines stay high (+5V) or low (0V) until reset through software.

Infrared Port Operation

The infrared port is used to transmit data to a control box, containing an infrared receiver, which in turn emulates the actions of the control pedal normally used with the sewing machine. The transmitter is tuned to transmit as far as 5 feet and within an angle of approximately 135 degrees. In order to minimize the probability of accidental transmission of signals to control boxes on neighboring sewing machines, a special ID code is be sent to the control box as part of the data. Each

control box is setup to recognize its specific ID and not recognize other IDs. A wildcard ID of 7 will be recognized by all interface boxes.

Serial Port Operation

The serial port is used to transmit or receive data through a DB9 connector to other devices. This port is used to connect the VAST unit to an IBM compatible personal computer to download vocabulary data and upload voice reference patterns and other data. The port communications parameters are 9600,N,8,1.

Speech Output

Speech output is produced in either the form of synthesized sounds or playback of pre-recorded sounds. The synthesized sounds are pronounced in a male voice while the pre-recorded sounds are pronounced in a female voice. Each word to be sent to the speaker or earphone is first matched against a list of pre-recorded words, and if found, is pronounced in the female voice. If no match is found then the word is synthesized, according to a heuristic, to produce a phonetic approximation to the pronunciation of the word and spoken in the male voice. Intentional misspellings of words, to produce a phonetic representation of the spelling, may produce a better approximation than the phonetic representation of the correct spelling. Intentional misspellings, in which the first letter of the word is doubled, will force the VAST unit to synthesize the pronunciation of the word in a male voice and perhaps yield a more consistent speech representation, since not all words desired in the vocabulary are represented with pre-recorded speech.

Commonly Adjusted Parameters

The three parameters described below are commonly used to control and improve recognition using the VAST unit.

Gain

The "gain" parameter is similar to a volume control and should be adjusted to optimize recognition. This parameter is important in recognition since an operator tends to increase vocal effort to hear his/her voice in noisy environments. In these cases, a lower gain will help to maintain a better signal-to-noise ratio and thus improve recognition capability. The gain can be set within a range of 0 to 255. A reduction of the count by a factor of 2 corresponds to 6db; hence, the range of 255 to 0 is equivalent to 48db of attenuation relative to the maximum gain. Typical gain values range from 180 to 225, with 210 being suitable for many environments.

Reject Threshold

After a word has been spoken, it is matched with the set of voice reference patterns collected during training. Depending on how well the voice pattern of the word matches, the box selects two words that match closest. These two words are each given a score between 0 and 128 that reflects how well they matched. Each word will only be considered as a candidate if its score exceeds the "Reject Threshold" value. If no words are scored as candidates, no action is taken. If only one of them exceeds the threshold then an action corresponding to that word is performed.

Delta Difference

If both words exceed the reject threshold the "Delta Difference" parameter is used. In this case the difference between the scores of these words must be greater than the "Delta Difference" before recognition is determined as correct and before an action is taken. This process avoids ambiguities in recognition when two words exceed the reject threshold but are very close in score.

Training Parameters

An important training parameter is the Training Reject Threshold, TTHL. When a word is trained, or when one is recognized, the amplitude normalized and time compressed voice pattern is compared with that in memory and a score is computed. If the score in training does not exceed TTHL, reprompting of the word being trained occurs since the prompted word does not agree sufficiently with prior training of the same word. TTHL is automatically incremented with training passes.

The Tflag parameter is used to control the communication connection of the voice box to the user. The TFlag character has values 0, 1 or 2 which specify the following communication modes:

TFlag	Communication Modes
0	Serial RS-232 only
1	Voice Prompting via Text-to-speech only
2	Serial communications and Text-to-speech

Other Parameters

A process called dynamic background subtraction is used to detect the beginning and ending of a word. Following detection of each word or phrase the average

energy, during non-speech is computed and subtracted on a per filter basis from the next word detected. After the background noise is subtracted, if the absolute value of the sum of the change in energy over all 16 filters (spectral energy change) exceeds a value denoted by T1; the beginning of a word or phrase is noted and the filter information is saved. If the spectral energy of the filters exceeds the parameter T2, after exceeding T1, then additional speech samples are saved. If the spectral energy change is less than T2 for a threshold count denoted by ETHL, the end of the word or phrase is marked. However, if the spectral energy change falls below T2 for less than ETHL counts, then exceeds the value T2 before ETHL counts, ETHL is set to zero and the counter restarted (inter-word/phrase pause). The information thus stored is then used for training or recognition, provided that the number of significant samples of the word/phrase exceed a value set by the parameter MINSM. New audio spectra are collected every 6 milliseconds, hence a value of MINSM = 20 corresponds to at least 120 milliseconds of speech. If the value of MINSM is not exceeded, collected data is discarded and not classified.

There are two other hardware dependent parameters which the user is not allowed to access. These are the NT and ET parameters and are set to a value of 2 each. The default values selected are for a quiet environment. Since T1 and T2 are also set to these conditions, in a noisy environment they may be increased to prevent false word boundary detection. In general, in a noisy environment the gain should be lowered. While setting these parameters the user can check to see if the Word Boundary LED on the voice box comes ON in the environment when the operator is not speaking into the microphone. If the LED is ON continuously or if it blinks randomly, then the gain must be lowered first until the LED goes OFF. Next, the user should verify if the system trains without skipping over sequential training word prompts. If this occurs, T1 and T2 should be increased by 4 counts until all sequential training prompts are obtained.

Train Button

This button is found on the face plate of the VAST unit and is used to initiate training without connection to a PC. Pressing and releasing the button once will initiate a process that prompts the user for each word in the vocabulary through either the headphone or optional speaker on the VAST unit. As prompting for each word is made, the user must speak the same word in the same manner as training while connected to a PC. A total of 7 passes (or whatever number of passes was used during initial training) is made.

Update Button

This button is found on the face plate of the VAST unit and is used to initiate an update to the voice reference patterns in the unit without being connected to a PC.

Pressing and releasing the button once will initiate a process that prompts the user for each word in the vocabulary through either the headphone or optional speaker on the VAST unit. As prompting for each word is made, the user must speak the same word in the same manner used during initial training. Only a single update pass is made over the vocabulary. If recognition of a single word in the vocabulary has been troublesome, then when that word has been prompted for update training, the update training button should be pressed again. At this point, that single word will be trained from start with 7 (or whatever number) passes.

Increase Gain Button

If the train button on the VAST unit is held down for an extended period of time, the speaker (or headset) gain settings are spoken in an increasing sequence, starting with the current gain, in steps of 5. When the desired gain setting is reached, the train button should be released and the last spoken value will remain at the current gain setting.

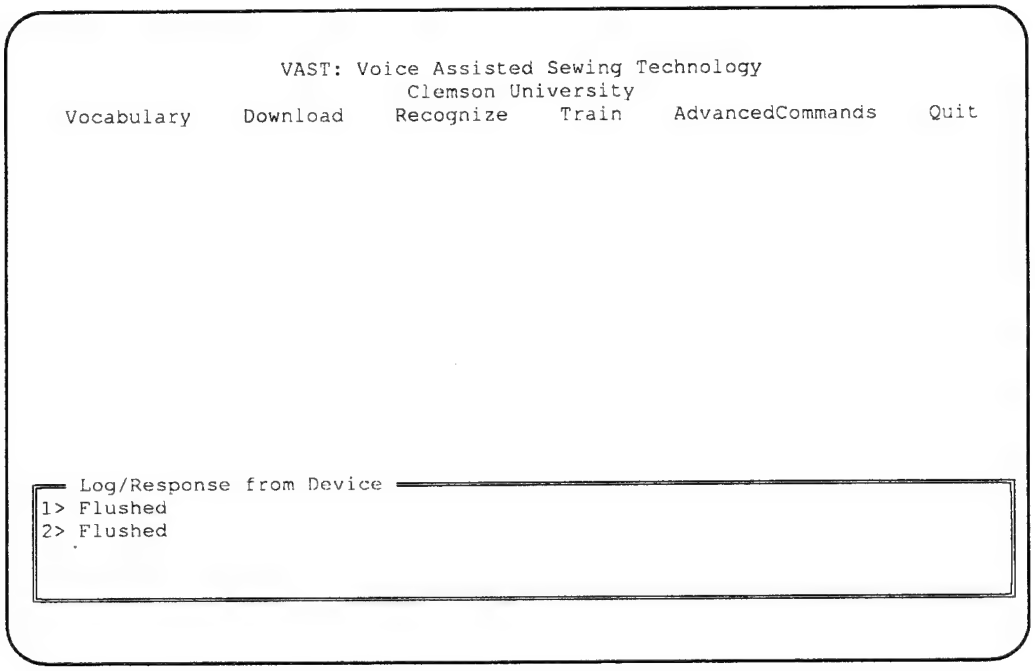
Decrease Gain Button

If the update button on the VAST unit is held down for an extended period of time, the speaker (or headset) gain settings are spoken in a decreasing sequence, starting with the current gain, in steps of 5. When the desired gain setting is reached, the update button should be released and the last spoken value will remain at the current gain setting.

SOFTWARE OPERATION

The VAST software uses a pull-down, menu-driven interface. An on-line help can be accessed by pressing the F1 key after moving the highlighted bar over the command for which help is required. To select any option the user either uses the arrow keys to move the highlighted bar over the option and then presses the enter key, or the user presses a hot key which denotes that option. The hot key for every option is highlighted in a different color. Another window, permanently displayed at the lower portion of the screen, displays the responses from the VAST unit.

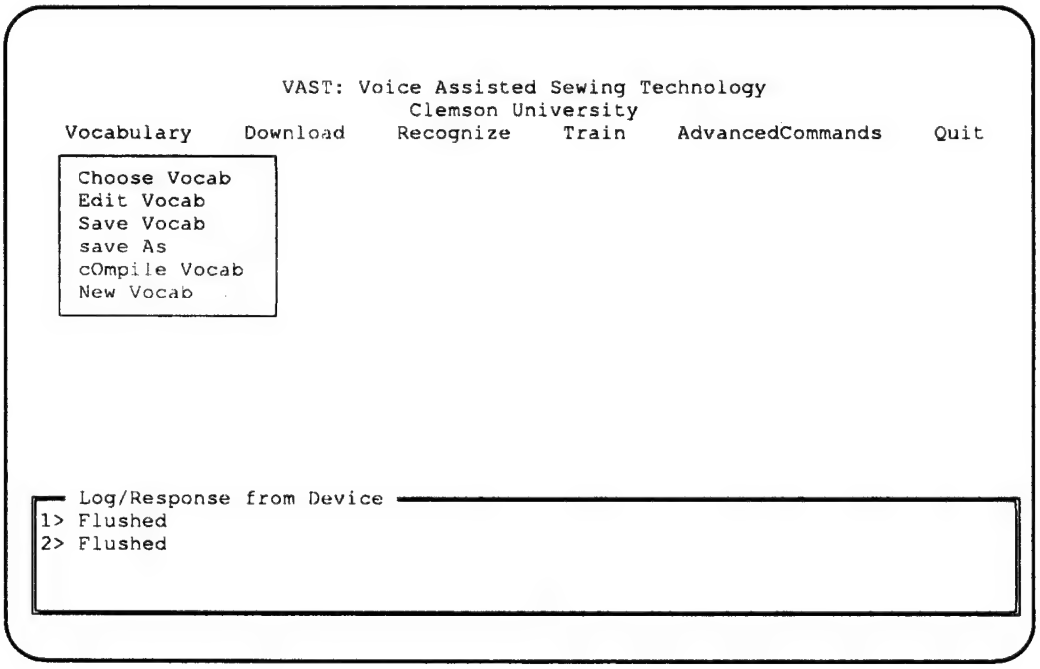
Main Menu



Vocabulary	Creates vocabularies or makes changes in existing vocabularies. Also used to compile vocabulary into an internal format downloaded to the VAST unit later.
Download	Enables a user to download voice reference patterns, vocabularies and/or parameters to the VAST unit.
Recognize	Enables the recognition capability of the VAST unit to be tested after training.
Train	Enables to VAST unit be trained or updated with a person's voice.
Advanced Commands	Enables configuration of the VAST unit's parameters and verify that the VAST unit is in good working condition.
Quit	Exits the system and returns to DOS.

Each of the options provides a sub-menu as shown below.

Vocabulary



Choose Vocab Enables the user to view a previously created vocabulary. Another window is displayed on the screen showing files in the current directory. To select a file the user can move the highlighted bar using the up- and down- arrow keys and then press the enter key when the bar selects the file to be viewed.

Edit Vocab Enables the user to make changes to the vocabulary displayed.

Save Vocab Saves the vocabulary with its current filename. An existing file will be overwritten or a new file will be created if none exists.

Save As Saves the vocabulary on the hard disk with another filename.

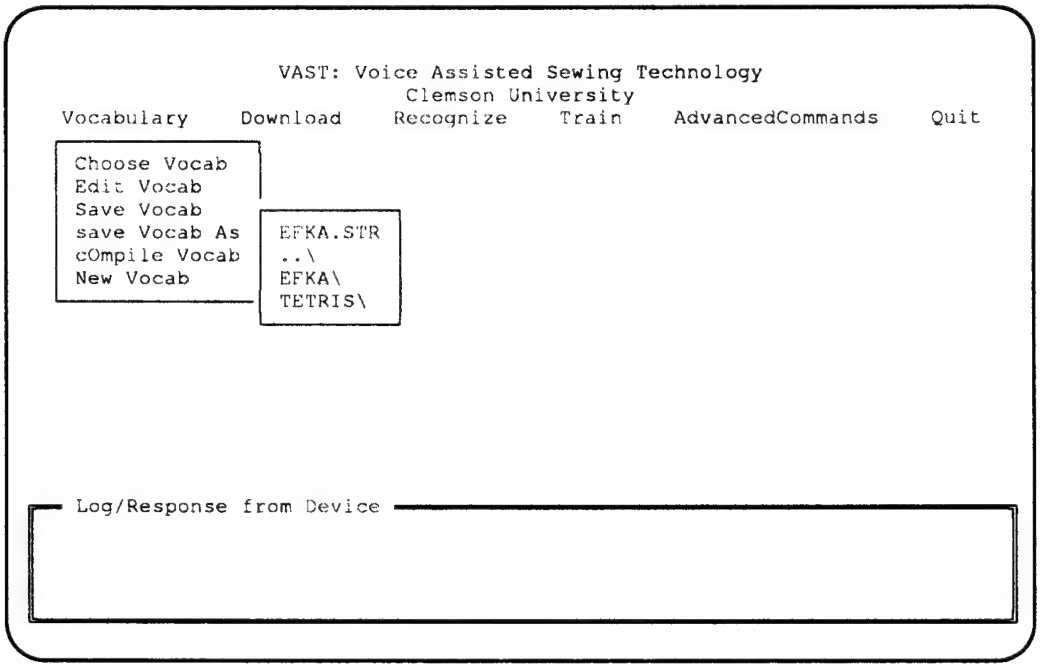
compile vocab Compiles a vocabulary that is created or changed before downloading to the VAST unit.

New Vocab Creates a new vocabulary.

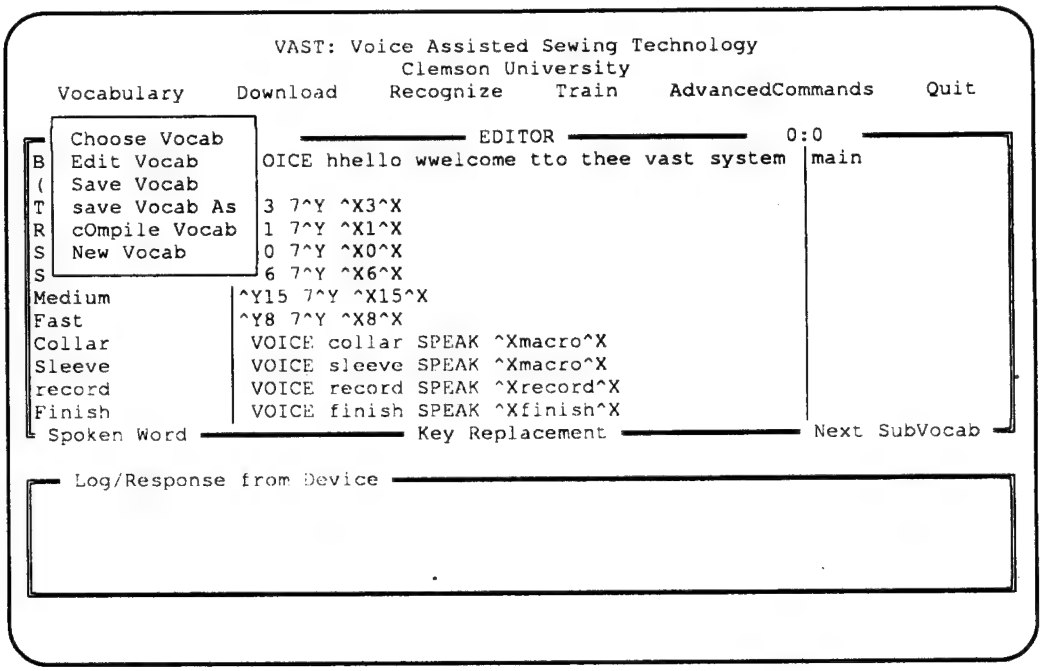
***note*:** Before the "**compile vocab**" option can be taken, a vocabulary must be chosen, using the "**Choose Vocab**" option, or created using the "**New Vocab**" option.

Choose Vocabulary

The selection of this menu option results in the following screen display:

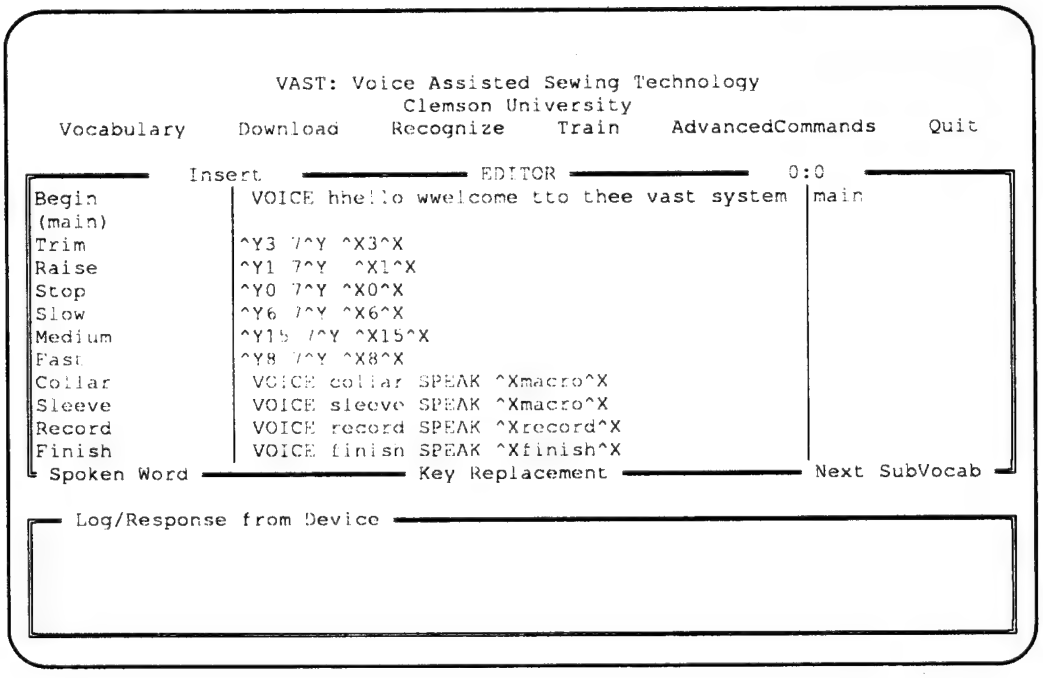


The submenu window displayed lists all vocabulary files available for selection, as well as subordinate subdirectories to which the user may switch. Selection of the desired vocabulary file results in the following display:



Edit Vocab

The selection of this menu option results the following display which enables changes to be made to the vocabulary:



The information on this display consists of two windows, one for vocabulary table and one for Log/Response from the VAST device while testing. The vocabulary table window holds three columns containing, from left to right, the words to be used in the vocabulary, the actions to be taken as a result of recognition of the words and a subvocabulary to be transferred to upon recognition. This example shows no subvocabulary.

Pins on the parallel port are controlled with data surrounded by ^X (control X) delimiters in the action column while data surrounded by ^Y (control Y) delimiters are transmitted through the infrared port. Data not surrounded by any special characters are transmitted through the serial port.

In the display above the Begin line is used to mark the start of the vocabulary and specify an initial action to be taken when the unit is powered on. In this example, VOICE hhello wwelcome tto thee vast system SPEAK (the SPEAK word is outside the boundary of the window) instructs the VAST unit to synthesize speech corresponding to the words following the VOICE control word and send the speech to the speaker and the earphone when the word SPEAK is encountered. Some of the words are intentionally misspelled to improve the quality of the synthesized speech or to force the VAST unit to synthesize speech rather than replay pre-recorded speech (see page 5).

Each subvocabulary begins with a subvocabulary name in parentheses. The line with the (main) identifies the start of the first subvocabulary.

The line reading: Trim ^Y3 7^Y ^X3^X defines the word Trim to be associated with the action following the word. The ^Y3 7^Y indicates that a 3 should be transmitted out the infrared port with an identification code of 7 (the wildcard code, see page 4). Lines through the line containing Fast are similar.

Control Words

Special words are used to control speech output to the speaker or earphone. Each word is specified with a slash (/) and a letter. The letters available are:

V	VOICE
S	SPEAK

Macro Definition

The line reading: Collar VOICE collar SPEAK ^Xmacro^X defines a macro word. A macro word is a word to be associated with a collection of words spoken during the control of the sewing machine, along with the elapsed time duration between those spoken words. This feature provides for a type of learning mode whereby the VAST unit can record

the words uttered by the user and replay them at a later time when sewing an identical piece. The next line containing `Sleeve` starts another macro definition.

The line reading: `Record VOICE record SPEAK ^Xrecord^X` associates the word `Record` with the start of the macro recording session. In order to start the recording, the user will speak the word `Record` and then the word `Collar` or the word `Sleeve` (or any other macro defined in the vocabulary). The user will then speak other words like `Slow, Medium, Fast` etc, to sew the first garment part. The user will then speak the word `Finish` to terminate the macro recording session. In order to sew an identically shaped part as the last, the user can simply speak the word `Collar` or `Sleeve` and the VAST unit will execute the same actions as were earlier executed with the same elapsed times as earlier.

The line `Finish VOICE finish SPEAK ^Xfinish^X` defines the word used to terminate the recording session.

Save or Save as

The selection of this menu option results in the writing of the vocabulary to disk.

Compile

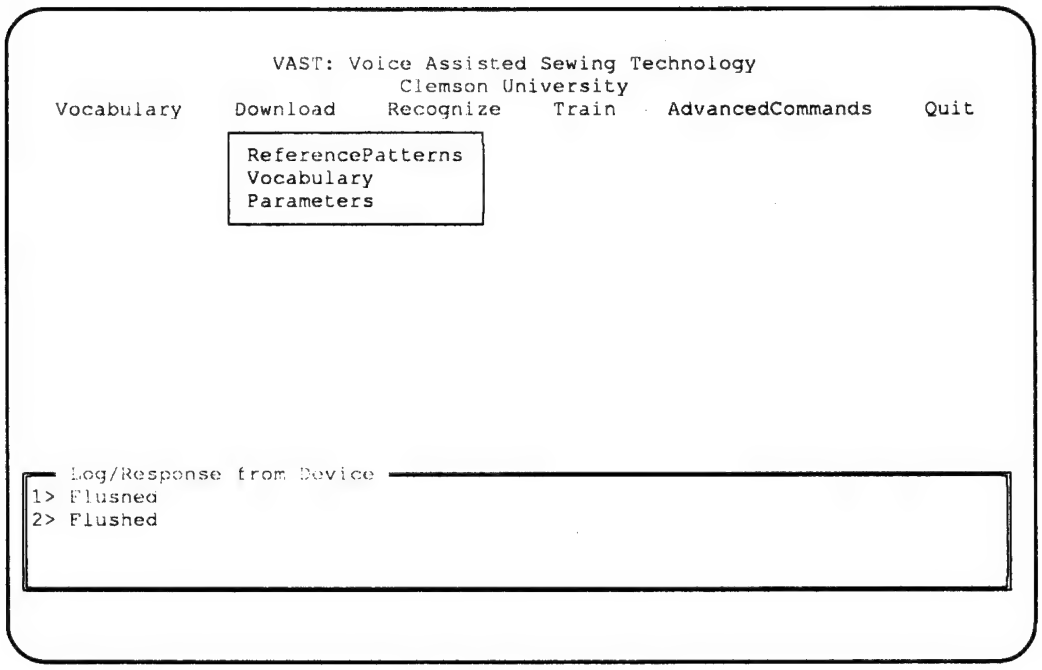
The selection of this menu option translates the vocabulary to a form suitable for use by the VAST unit during production.

New Vocab

The selection of this menu option presents an empty screen to be filled in.

Download

The selection of this menu option results in the following screen display:



Submenu options are:

Reference Patterns - This option allows the user to download a previously stored voice reference pattern to the VAST unit.

Vocabulary - This option allows the user to download a previously defined and compiled vocabulary to the VAST unit.

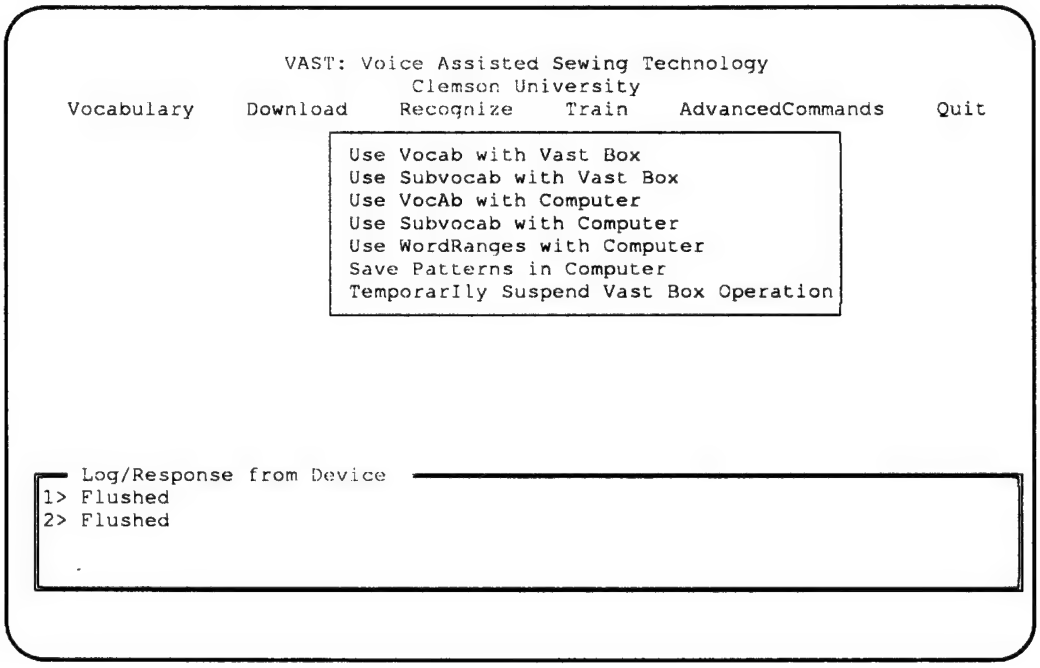
Parameters - This option allows the user to download a previously stored set of parameters to the VAST unit. These parameters must have been uploaded from the VAST unit at an earlier time.

NOTE: Before any of the above options are taken, a vocabulary must be selected with the **"Vocabulary"** option in the main menu.

The **"Recognize"** option provides a user options with which the recognition capability can be verified. The options are as shown in figure 6.

Recognize

The selection of this menu option results in the following screen display:



The first two options in the submenu display information in the Log/Response window near the bottom of the screen. This information is arranged as shown below:

05 RRFLAG WW# WWS RUW# Delta-Dif. WS
RS <CR>

where:

RRFLAG =	Reject Flag (three digits)
	1 = Recognized.
	0 = Rejected.
WW# =	Winning word number.
WWS =	Winning word score (max. = 128).
RUW# =	Runner-up word number (nearest neighbor).
Delta-Dif =	Difference Score (winner score - runner-up score).
WS =	Winning word
RS =	Runner-up word

The submenu choices are:

Use Vocab with Vast Box

This submenu selection enables recognition using the complete vocabulary contained in the VAST unit. After this selection is chosen

the VAST unit can be disconnected from the PC and used in a standalone mode.

Use Subvocab with Vast

This submenu selection is similar to the **"Use Vocab with Vast Box"** option except that the recognition is limited to a subvocabulary and not the entire vocabulary.

Use Vocab with Computer

This submenu selection enables recognition of all the words in the vocabulary but sends the results of recognition out the serial port to be displayed on the screen of a PC running the VAST PC software. The purpose of this selection is for testing the VAST unit for recognition prior to using in a production mode to control a sewing device. The VAST unit will not function in production after this selection is chosen; the **Use Vocab with Vast Box** selection must be made after this selection is made and before placing the VAST unit back into production.

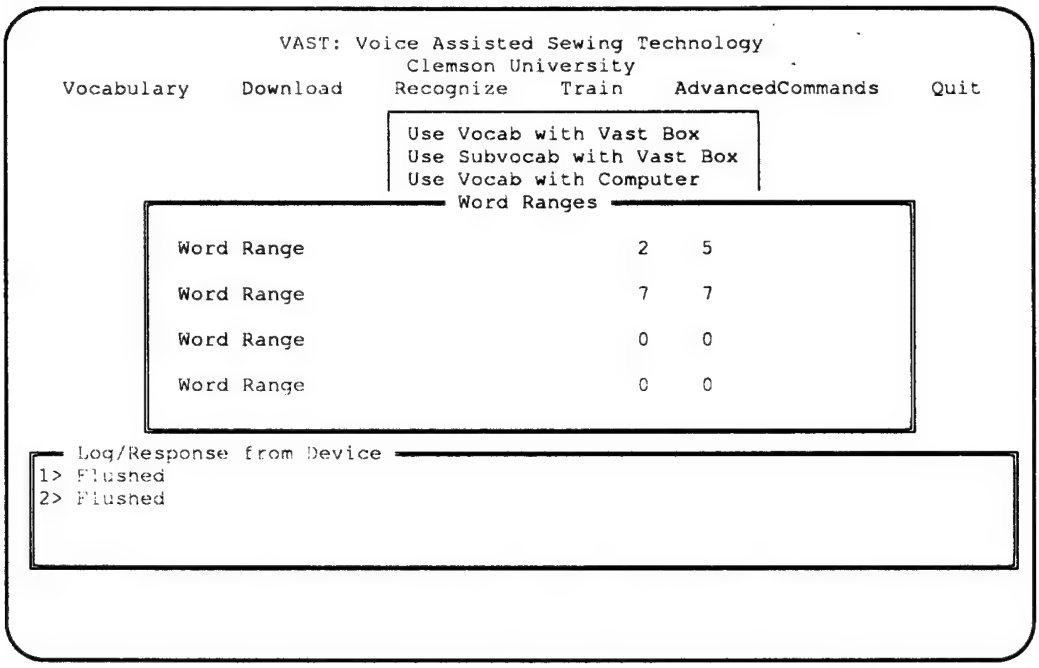
Use Subvocab with Computer

This submenu selection limits the recognition to a subvocabulary.

Use WordRanges with Computer

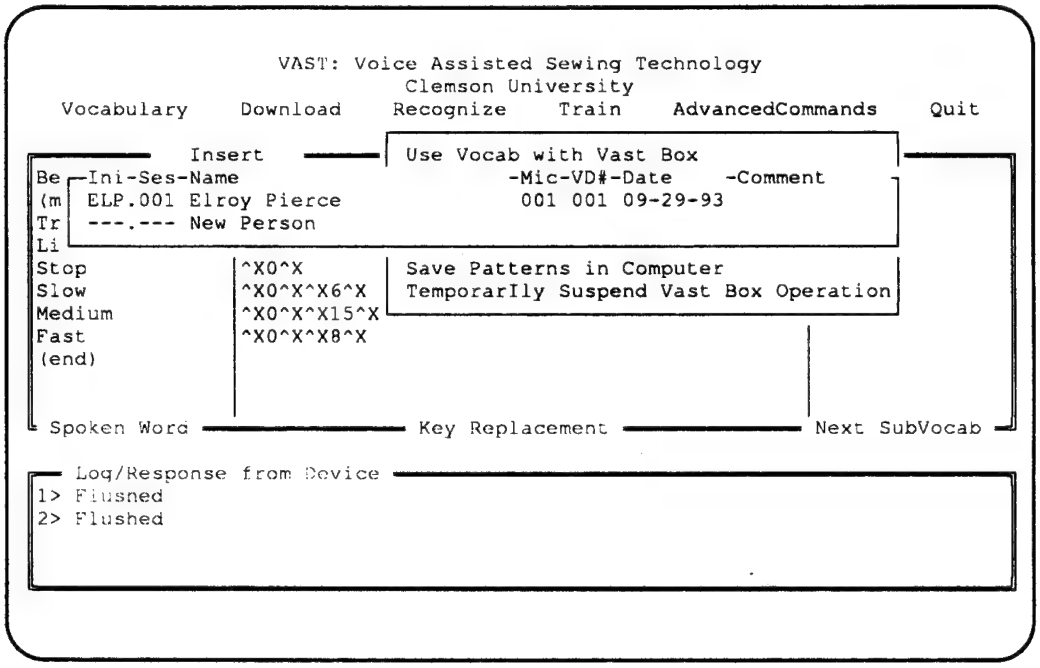
This submenu selection enables recognition with scoring of a restricted list of words. A lower and upper bound for the range must be specified. As many as four word ranges can be specified. In the figure below two such ranges are specified. The first specifies a range from word number two through word number five while the second range specifies only word number seven.

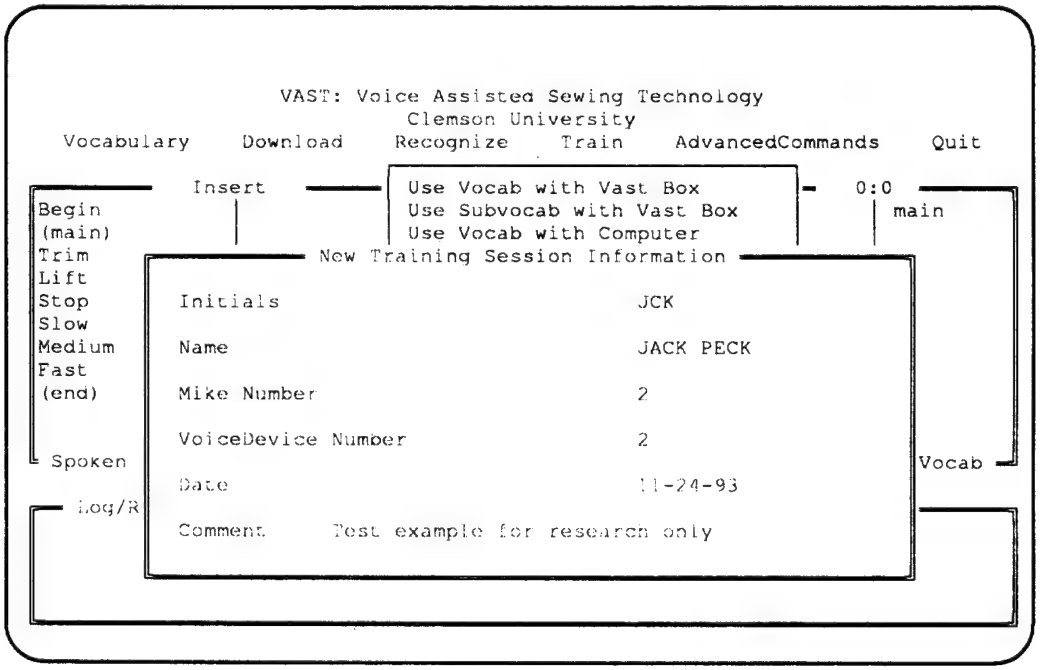
NOTE: The user must use the up and down arrow keys on the keyboard to move between fields in the window. After entering all the required data the Esc key must be pressed.



Save Patterns in Computer -

This submenu selection can be used to upload the voice reference patterns of the person who last trained the VAST unit and store them on a disk within a PC. A list of initials will be displayed and the user must select the initials of the person whose voice patterns are being uploaded. After selecting this option, a window as shown below pops up. The user must then either choose to store the patterns in a new file by selecting the **New Person** option or select a file created earlier. As shown in the example below, there is one file, called **ELP.001,** in which the voice patterns of a person named **Elroy Pierce** was stored earlier. If this option is selected then the contents of the file will be overwritten with the patterns in the VAST unit. If however, the **new person** option is selected then the user will be prompted to provide a new set of initials and a new file with these initials as it's name will be created. A new window will pop up as shown below and the user must fill in the person's initials, name, mike, VAST device number and a comment. After entry the user can press the Esc key on the keyboard to begin uploading the voice reference patterns. The user need not fill in all the fields although the initials field must be filled. Again the user must use the up and down arrow keys to move between fields.



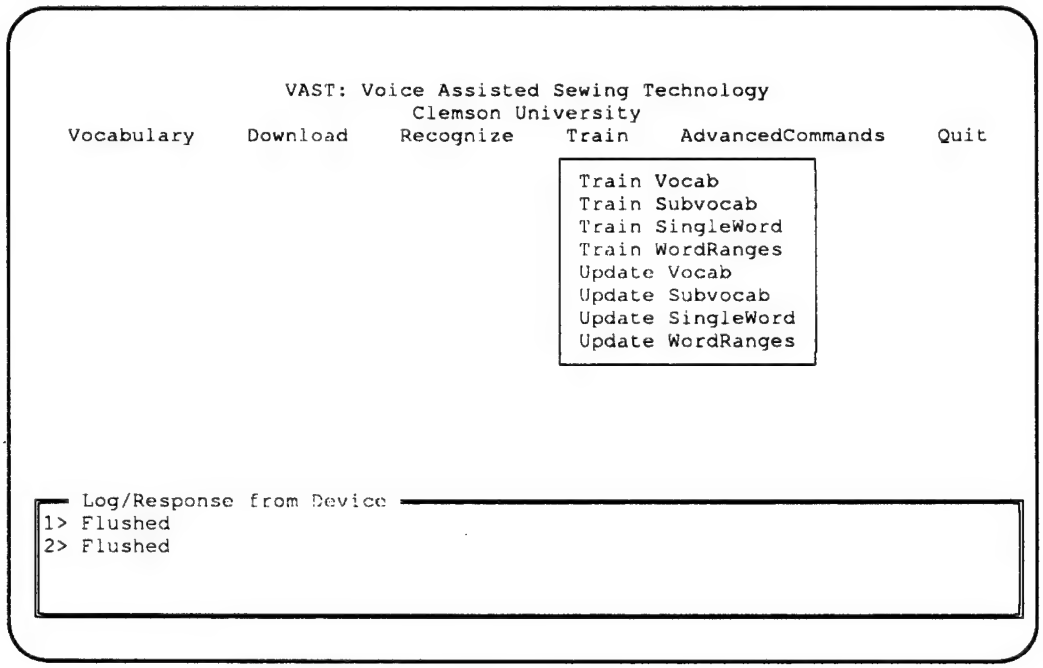


Temporarily Suspend Vast Box Operation -

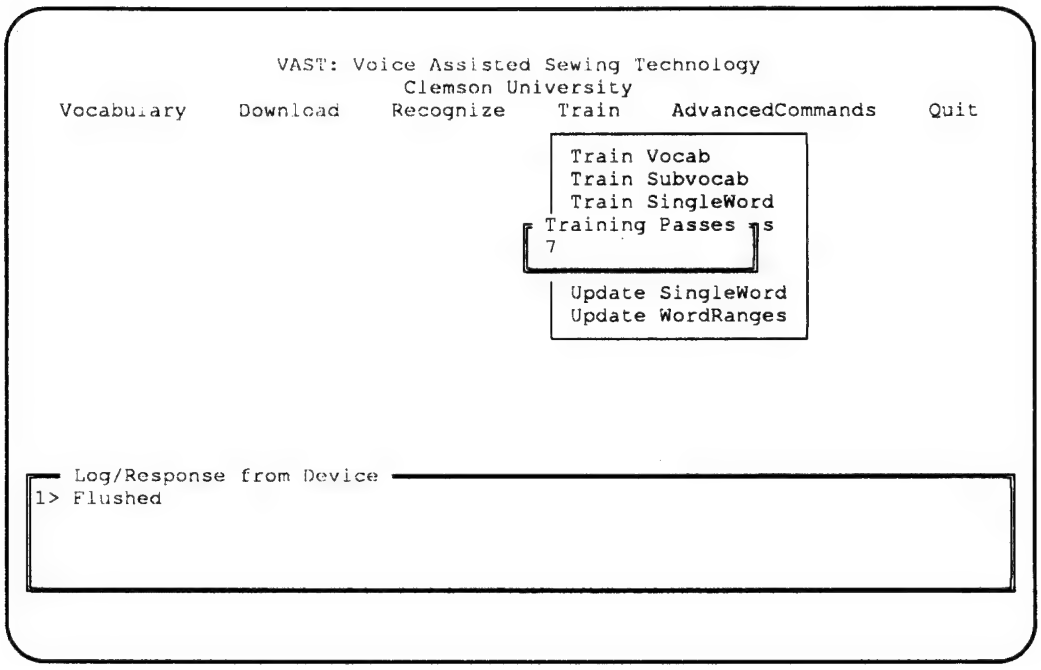
This submenu selection disables the VAST unit until one of the recognition actions is again chosen.

Train

The selection of this menu option results in the following screen display:



Train vocab - This submenu selection is used to train the VAST unit to recognize the entire vocabulary. The user will be prompted to enter the number of passes required for the training process. The default value is 7 as shown in the figure below. The response window displays a string of fields as shown below.



While training, the response window displays output in the following format for each word that is trained.

01 TCFLAG Word# TO NBA Prompt-string

where:

TCFLAG = A three digit flag whose value is either 001 or 002. If the flag is zero, training is incomplete; otherwise it is complete.

Word# = A three digit number of the word or phrase to be trained.
TO = Three digits which indicate the current training pass.
NBA = The number of bits in the input pattern which match (either 1's or 0's) the bits of the prior prompted word. This value, when it converges, insures reference pattern stability over time and speaker variance. On the initial training pass all 248 bits match, by definition, since this is the only pattern to date.

Train Subvocab - This submenu selection initiates training for a subvocabulary.

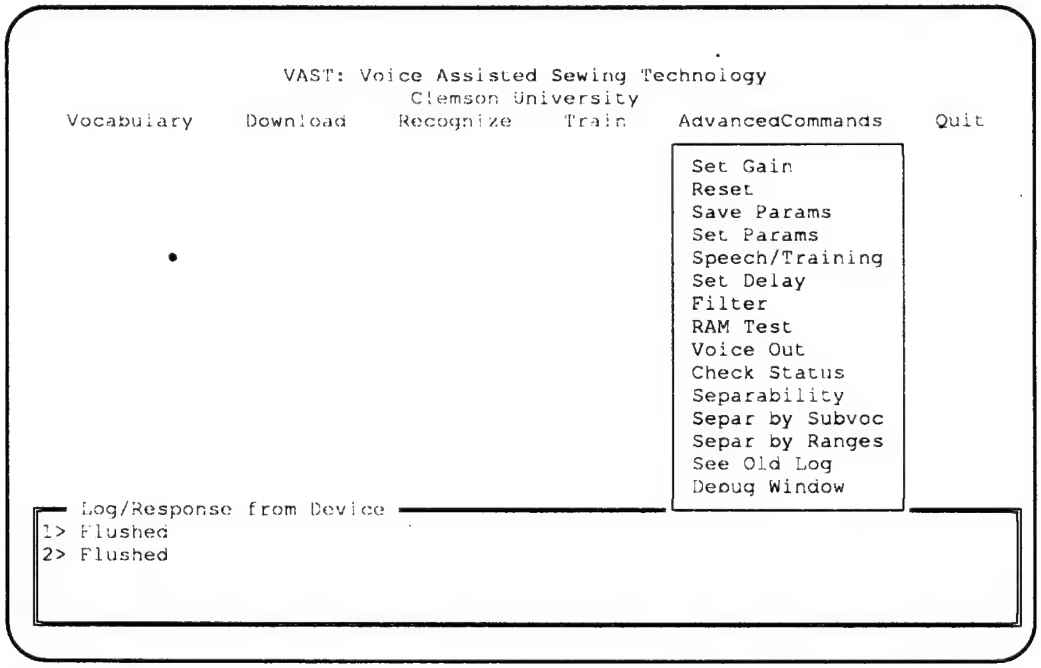
Train Singleword - This submenu selection initiates training for a single word.

Train Wordranges - This submenu selection initiates training for a range of words.

update options - These submenu selections are similar to the **"Train"** options except they do not reset the voice reference patterns before collecting samples. The update commands modify existing voice templates.

Advanced Commands

The selection of this menu option results in the following screen display:

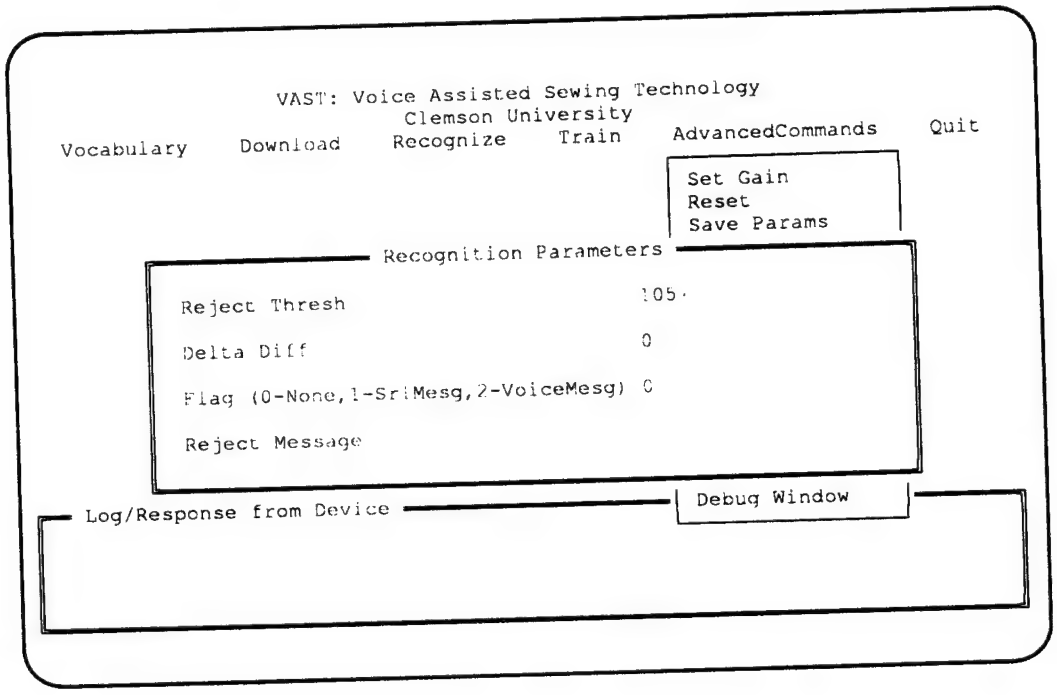


Set Gain - This submenu selection sets the gain parameter. (see page 6)

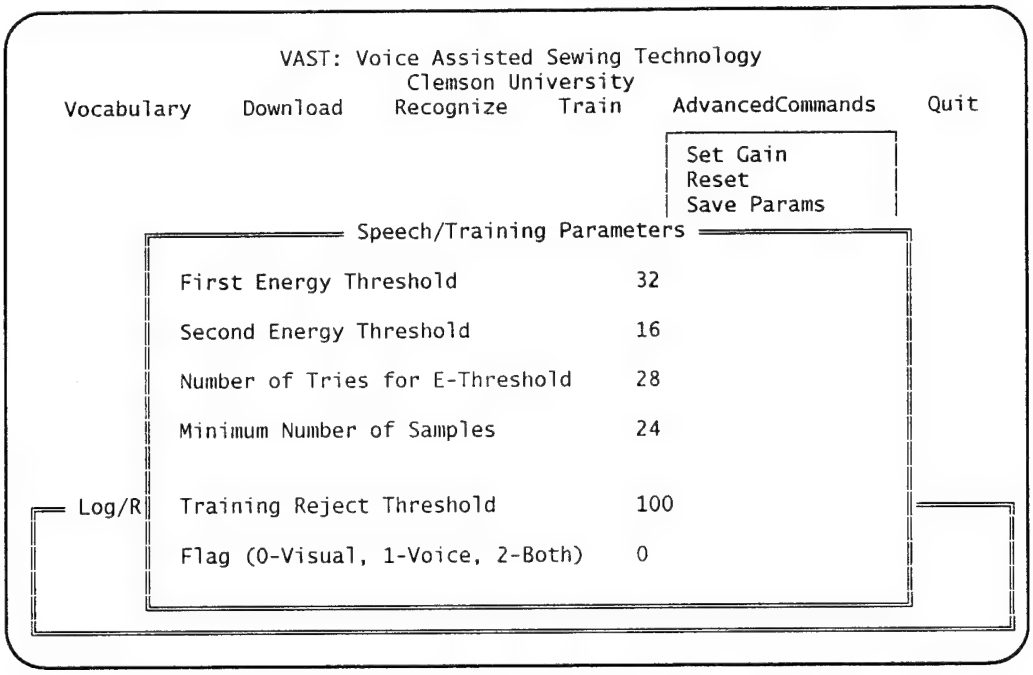
Reset - This submenu selection resets the VAST unit. All parameters are set to default values and vocabulary and voice pattern information are discarded.

Save Params - This submenu selection enables the user to ulpoad and store the control parameters of the VAST unit.

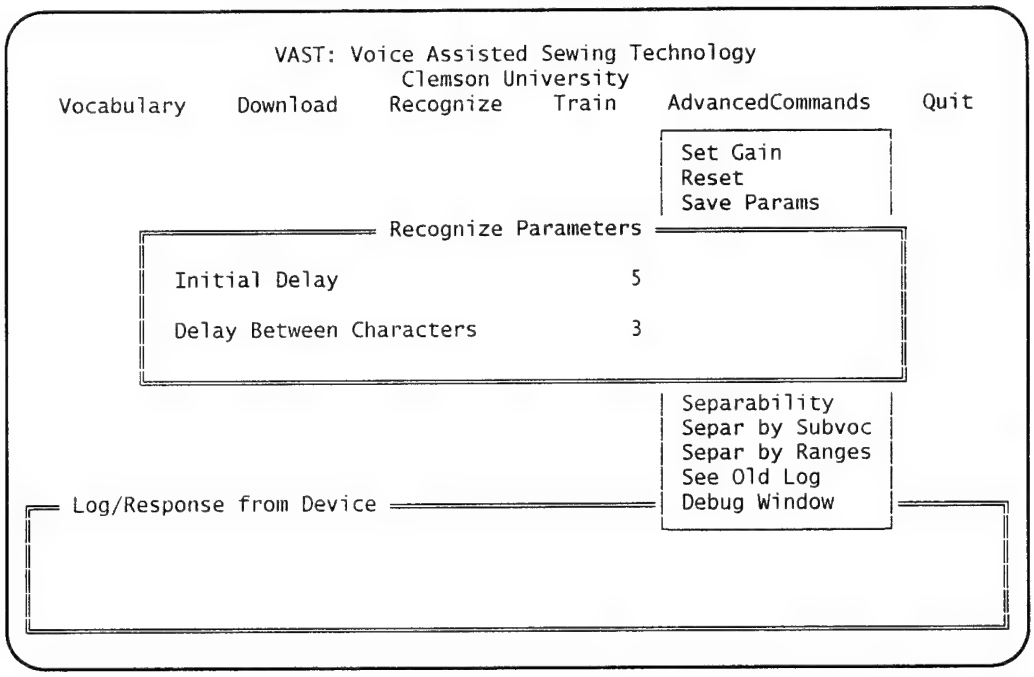
Set Params - This submenu selection can be used to set various recognition parameters described earlier in this manual. A window similar to that shown below pops up to enable the user to change the parameters.



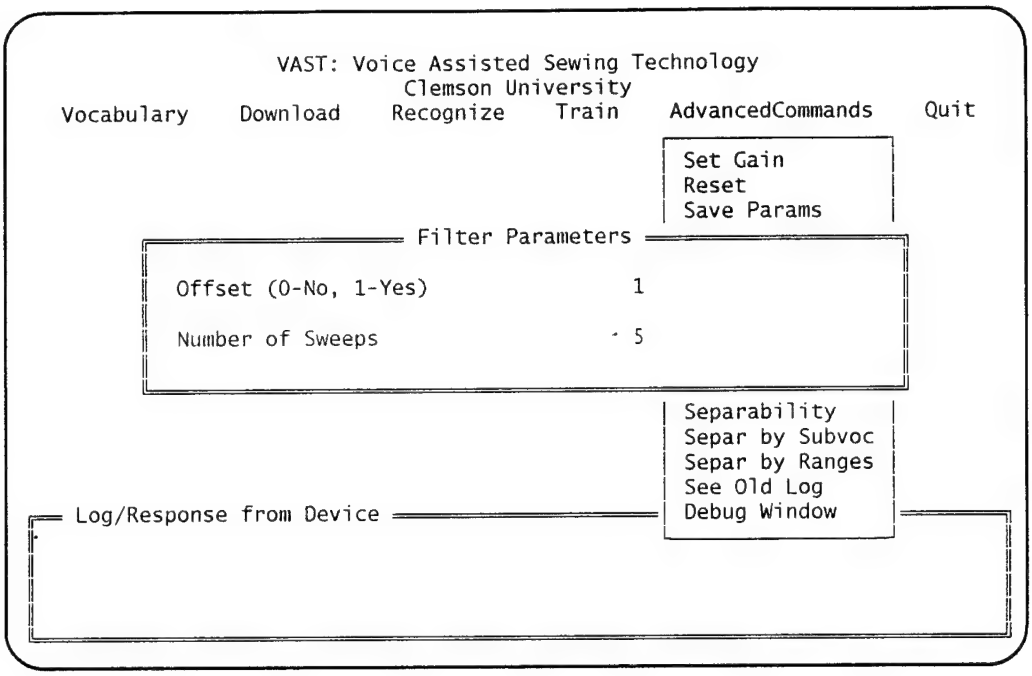
Speech/Training - This submenu selection enables the user to set speech and training parameters. (See page 6). A window which displays the current settings will pop up , as shown below.



Set Delay - This submenu selection allows the user to set an initial and inter-character delay time. Such delays can be used to allow sufficient time between outputs from the VAST unit. As shown in figure 15 the "Initial Delay" parameter determines the number of 50 millisecond slot delays between the recognition of a command and the output of the first character. The "Delay Between Characters" parameter determines the subsequent 50 millisecond intervals between characters in the output.



Filter - This submenu selection allows the user to perform a filter test. The first parameter is for background noise subtraction while the second parameter is the number of sweeps of the channel filter bank. It can be used to verify that the VAST unit is functioning properly, that the gain is set properly and to monitor and quantify the spectral distribution and energy content of background noise. The window shown below pops up on the screen and enables the user to read and/or change these parameters.



RAM Test - This submenu selection allows the user to ensure that all bytes of the static RAM are good.

Voice Out - This submenu selection allows the user the Text-To-Speech conversion of the VAST unit to be tested. This option can be used for experimentation with data supplied to the box for conversion to speech.

Check Status - This submenu selection allows the user the user to verify that the VAST unit is operational and that serial communication between the PC and the unit is functioning properly.

Separability - This submenu selection allows the user to determine the quality of the trained voice pattern set for all the words in the vocabulary. It causes the VAST unit to score each voice pattern and it's nearest neighbor, and to output the resulting pairs which are less than the value chosen. This command is important in determining which voice patterns are too close and hence may cause recognition substitution errors.

Separ by Subvocab -

This submenu selection is similar to the **"Separability"** option except that it works for any word in a subvocabulary.

Separ by Ranges -

This submenu selection is similar to the **"Separability"** option except that it works for words specified within a range. An upper and lower bound must be specified in a manner similar to the **"Word Ranges"** sub-option in the **"Recognize"** menu.

See Old Log -

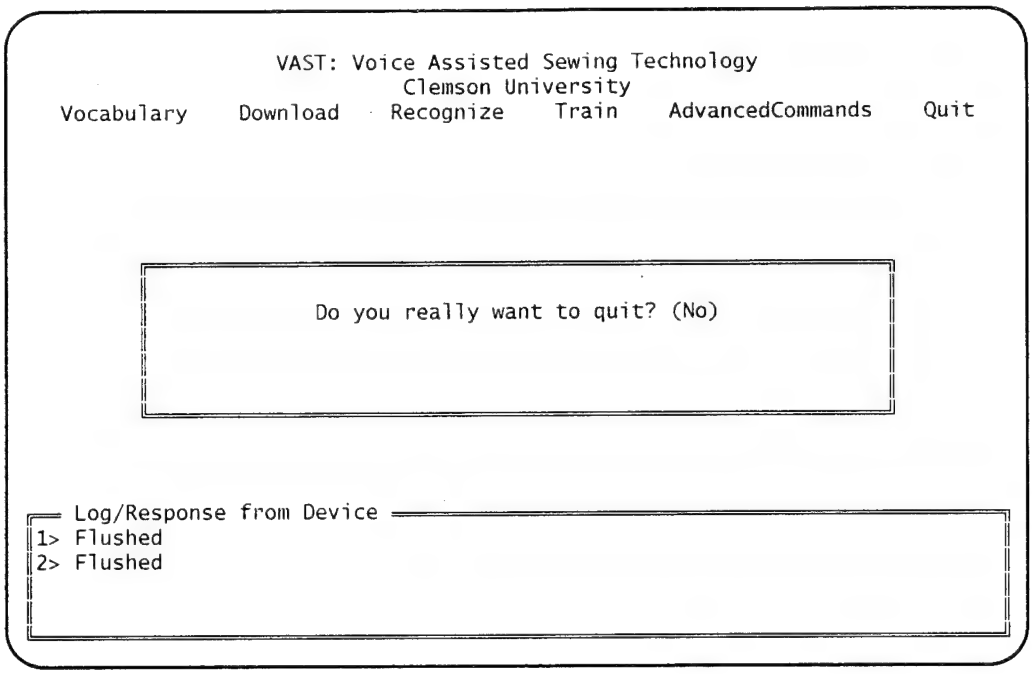
This submenu selection allows the user to view the log file.

Debug Window-

This submenu selection allows the user to toggle between two modes: the "debug" mode and the "user" mode. When the software is first started, it begins in the user mode by default. In this mode the display in the log window, during training and recognition, is more "user-friendly" with only a few parameters being displayed. In the "debug" mode however, the data displayed is much more cryptic. When the software is running in the user mode the menu displays "Debug Window" so that the user can switch to the debug mode. When the user is in the debug mode, the menu will display "User Window" instead; so that the user can switch back to the user mode.

QUIT

This menu selection will terminate the VAST software system. When selected, the user is prompted to confirm the choice as shown below and the user is required to press "y" to confirm and exit or "n" to return to the main menu.



A QUICK REFERENCE GUIDE TO USING THE VAST BOX

Before using the VAST unit it must be trained by the operator to recognize the vocabulary to be used. To do this there must already be available an existing vocabulary or the user must create a new one. The software package comes with a vocabulary which contains commands to control a sewing machine attached to an EFKA digital motor. The following steps should be executed in the order listed.

1 Connect the VAST box to the computer with the cable provided.

1. Select the **Choose Vocab** option from the **Vocabulary** menu. Select an option by either moving the highlighted bar over the option and pressing the **Enter** key or pressing the hot-key denoting that option.

2. When the software displays a window with all the vocabularies listed, the appropriate vocabulary should be selected. After selection, the software will retrieve and display the contents of the vocabulary.

3. The **Esc** key should be pressed to return to the **Vocabulary** menu.

4. The **Compile Vocabulary** option should be selected from the menu.

5. The compiled vocabulary must be downloaded to the VAST box by pressing **Esc** to return to the main bar-menu and selecting the **Download** menu.

6. After the vocabulary has been downloaded, the box must be trained. Press the **Esc** key to return to the title bar and then select the **Train** menu.

7. Select the **Train Vocab** option and a window stating that 7 training passes will take place, will pop up.

8. Training will begin when the **Enter** key is pressed. The Log response window (at the bottom of the screen) will prompt for words to be spoken. These words should be spoken as consistently as possible until the training is completed. If a word is spoken somewhat differently from pass to another, the VAST unit may request that the word be spoken several times in a row. Do not be concerned, just speak the word as many times as requested in as consistent a manner as possible. If the training session is to be aborted, the **Esc** key should be pressed.

9. After training press the **Esc** key to exit to the title bar and select the **Recognize** menu to prepare the box for use as outlined in the next two steps.

10. To test the recognition capability of the VAST unit, the **Use Vocab with Computer** option should be selected and the words in the vocabulary should be spoken, one at a time, into the microphone. The VAST unit will attempt to match each word spoken with one of the words trained earlier and the result of the matching process will be displayed on the Log Response window. By this means, the recognition accuracy of the box can be verified. Once the recognition accuracy is determined to be adequate, the next step should be completed to begin use of the box to control a device.

11. To start using the box to control a device, select the **Use Vocab with Vast Box** option. A message stating that the vocabulary is now active through Power Down/Up will be displayed. At this point the box can be disconnected from the computer and used to transmit infrared signals to the interface box near the sewing machine. ***This option must always be selected before disconnecting the box from the computer.***

TROUBLESHOOTING

If the VAST unit is not responding satisfactorily to the voice commands, the following procedure should be used in problem determination:

1. Check all the connections and verify that the box is powered ON. Check if the words spoken into the microphone are being detected by the box by checking that the LED labeled "IN" lights-up every time a word is spoken.

2. If the LED is ON continuously or blinks randomly when nothing is spoken then the background noise is probably too high and the voice box parameters must be adjusted to this environment. First reduce the gain till the LED is OFF for the background noise. Now during training if the box skips over sequential training word prompts then increase the T1 and T2 speech parameters by 4 counts until all sequential prompts are obtained.

3. If the command recognition capability is not satisfactory then reducing the gain might help. This will enable the box to recognize words more accurately.

4. If the performance is still not satisfactory then connect the VAST unit to the PC and go to the "Recognize" option and verify that the score for the word spoken is well above the Reject Threshold. It could be that at times the score computed falls below RTHL and hence the box takes no action. In this case either reduce the RTHL value or re-train the box to all those words for which recognition is a problem.

5. It could be that the recognition problem is due to two or more words scoring high and thus causing recognition substitution problems. If two or more words have scores that fall within Delta Difference then the voice box will not take any action. In this case, the Delta Dif. parameter can be reduced (if it has a value greater than 0) or the voice box can be re-trained for those words.

NOTE: It is always safer to use words that do not sound similar while designing the vocabulary. Words that sound similar might make differentiation a problem.

TIPS ON CONTROLLING OUTPUT

1. Parallel Port Control.

The voice box provides output on its parallel port in response to recognized voice commands or phrases for:

a. Serial I/O on RS-232 lines,
b. On board voice output,
c. 8 bit parallel port output typically to control relays.

The parallel port output provides 2 milliamps for each of the output lines. The table below lists the bit positions, control code required to activate the particular bit and DB-25 pin assignment.

Bit	Control Code	DB-25 Pin
P7	128	14
P6	64	15
P5	32	16
P4	16	17
P3	8	22
P2	4	23
P1	2	24
P0	1	25
Gnd		7

The vocabulary defines the control line outputs on the parallel port. Parallel port control is obtained by framing a number from 1 to 255 by CONTROL X (^X) in the key replacement area while editing a vocabulary. Each number can be followed by a space and a second number between 1 and 999. The second number is the number of 50 milliseconds time intervals for the particular bit selected to remain active (high). If the second number is missing the parallel port latches until the particular bit is activated again (toggled).

Combinations of bits can be activated and separately or jointly deactivated. The key replacement string can have output to the serial port, output to the synthesizer or output to the parallel port in any combination.

Example :

1. Activate / Deactivate bit 7

   Spoken Word - Toggle Seven
   Key replacement- ^X128^X

2. If more than one output number is specified in the string then the voice box outputs an exclusive OR of the numbers.

   Key replacement - ^X3^X^X8^X
   Output - 0B Hex.

3. Pulse bit 7 for 3 seconds

   Spoken word - Pulse seven
   Key replacement - ^X128 60^X

4. The time delays specified for all numbers will be accounted for simultaneously.

   Key replacement - ^X3 60^X^X8 80^X
   Output - 0B Hex for 3 seconds and then 08 Hex for 1 more second.

2. Serial Port Control.

The output port on the VAST box can also be used as a serial port. To transmit data serially, the key replacement field of a vocabulary should contain the character to be transmitted. The difference now, is that the character should not be delimited by the ^X character as have been shown in previous examples. When the ^X character is used as a delimiter the character is transmitted using the port as a parallel port.

3. More control on the parallel port.

A delay can be inserted before the voice box can produce any output on recognizing a voice input. Other delays can also be inserted between output actions in the key replacement string. The user can set the initial delay and between character delay parameters to control them.

4. Using infrared to control the motor.

The voice box can now also communicate to the motor control box via infrared transmission. This enables the user to eliminate the cable connecting the two boxes thus giving greater mobility to the user. It also has another advantage in that one box can be used to control more than one motor. The user is only required to face the box in the direction of the control box when giving the command.

To enable the infrared capability of the box the user only has to replace the ^X characters in the vocabulary to ^Y characters. This character notifies the box to use infrared to communicate to the control box rather than through it's parallel port.

TIPS ON CONTROLLING MOTOR SPEED

The motor can be controlled by changing the control code in the key replacement field of the vocabulary. The control code numbers for various speeds are as shown below:

Action	Control Code
Foot Lift & Trim	3
Foot Lift Only	1
Stop (Neutral Pedal)	0 2
Slow (Positioning)	6 7 5 4 12 13
Medium	15 14 10 11 9
Fast	8

TIPS TO IMPROVE RECOGNITION

1. Try to use words that have multiple syllables. This will help in differentiating them from other audible sounds during recognition.

2. Avoid the use of words that sound almost the same.

3. Sometimes using each word in the vocabulary twice improves recognition. That is, the vocabulary now contains each word twice with the same key replacement field for both. The reason for improved recognition is that every time a word is being matched, the two words that match closest are considered. If these two words are the same then the probability that a wrong word is recognized is greatly reduced. Of course, this would mean that the vocabulary now contains twice as many words as the number of commands and the user will have to train twice as many words. If this technique is used the DELTA DIFFERENCE parameter must be set to zero.

4. In general, in a noisy environment the gain should be lowered. If the Word Boundary LED comes ON continuously or blinks randomly when the user is not speaking into the microphone, then the gain must be lowered first until the LED goes OFF. Now, the user should verify if the system trains without skipping over sequential training word prompts. If this occurs, T1 and T2 should be increased by 4 counts until all sequential training prompts are obtained.

Appendix B

Technical Description

Issued Patent
and
Pending Patent Application

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October 13, 1994

Dr. John C. Peck
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Pendleton, SC 29670-1957

RE: U.S. Patent Application entitled
APPARATUS AND METHOD FOR VOICE
CONTROLLED APPAREL MANUFACTURE
Inventors: John C. Peck
Randy Rowland
Duanpei Wu
Serial No.: Not yet assigned
Filed: Not yet filed
Our Reference No.: CXU-153

Dear John:

Please give this matter your immediate attention.

Enclosed is the application for U.S. Letters Patent covering the captioned invention. In addition to the written specification, 10 sheets of informal drawings, a Declaration and Power of Attorney form, and a Small Entity Status form, the enclosed documents include an Assignment to Clemson University and three One Dollar assignment fee checks, one for you, one for Randy Rowland, and one for Duanpei Wu.

Please get together with Duanpei so that you and Duanpei can review all of these documents for accuracy and completeness and ensure that the written description, drawings and claims properly describe the subject invention, including the preferred embodiments. If after your review you desire to make any changes in any portion of the application, please call me to discuss it before marking any of the documents. Upon completion of the review, if you determine that the application is satisfactory in all respects, each inventor must sign and date the Declaration and Power of Attorney form where I have checked in pencil.

When signing the Assignment, please do it in the presence of a Notary Public on the same day as you sign the Declaration and

PATENT

ATTORNEY DOCKET NO.: CXU-153

JOINT INVENTORS' ASSIGNMENT OF WORLDWIDE RIGHTS

WHEREAS, WE, JOHN C. PECK, a citizen of the United States, residing at 1548 Fort Hill Drive, Seneca, South Carolina 29678; RANDY ROWLAND, a citizen of the United States, residing at 1071 Skipstone Ct., Watkinsville, Georgia 30677; and DUANPEI WU, a citizen of People's Republic of China, residing at 19-A Daniel Drive, Clemson, South Carolina 29631, as ASSIGNORS, have invented jointly the inventive subject matter claimed in a United States Patent Application entitled APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE as described in a patent application for which we have signed a Declaration on the same date as we have signed this Assignment; and which is a Continuation-in-Part Application of U.S. Application Serial No. 08/155,100 filed on November 19, 1993, which is a Continuation Application of U.S. Application Serial No. 07/763,347, filed on September 20, 1991; and

WHEREAS, CLEMSON UNIVERSITY, a body politic and corporate under the laws of the State of South Carolina, whose post office address is Clemson University, Clemson, South Carolina 29634, as ASSIGNEE, is desirous of securing my entire right, title, and interest in and to this inventive subject matter in all countries throughout the world, and in and to the application for United States Letters Patent on this inventive subject matter and the Letters Patent to be issued upon this application and any

divisionals and continuations thereof;

NOW THEREFORE, be it known that for and in consideration of the sum of One Dollar ($1.00) in hand paid and other good and valuable consideration, the receipt of which from ASSIGNEE is hereby acknowledged, I, as ASSIGNOR, have sold, assigned, transferred, and set over, and do hereby sell, assign, transfer, and set over unto the ASSIGNEE, its lawful successors and assigns, my entire right, title, and interest in and to this inventive subject matter and this patent application, and all divisions and continuations thereof, and all Letters Patent of the United States which may be granted thereon, and all reissues thereof, and all rights to claim priority on the basis of such application, and all applications for Letters Patent which may hereafter be filed for this inventive subject matter in any foreign country and all Letters Patent which may be granted on this inventive subject matter in any foreign country, and all extensions, renewals, and reissues thereof, and I hereby authorize and request the Commissioner of Patents of the United States and any official of any foreign country whose duty it is to issue patents on applications as described above, to issue all Letters Patent for this inventive subject matter to ASSIGNEE, its successors and assigns, in accordance with the terms of this Assignment;

AND, I HEREBY covenant that I have the full right to convey the interest assigned by this Assignment, and I have not made and will not make any agreement in conflict with this Assignment;

AND, I HEREBY further covenant and agree that I will,

without further consideration, communicate with ASSIGNEE, its successors and assigns, any facts known to me respecting this inventive subject matter, and testify in any legal proceeding, sign all lawful papers when called upon to do so, execute and deliver any and all papers that may be necessary or desirable to perfect the title of this inventive subject matter in said ASSIGNEE, its successors and assigns, execute all divisional, continuation, and reissue applications, make all rightful oaths and declarations and generally do everything possible to aid ASSIGNEE, its successors and assigns, to obtain and enforce proper patent protection for this inventive subject matter in the United States and any foreign country, it being understood that any expense incident to the execution of such papers shall be borne by the ASSIGNEE, its successors and assigns.

IN TESTIMONY WHEREOF, I have hereunto set my hand.

_____
JOHN C. PECK

_____
DATE

STATE OF SOUTH CAROLINA)
COUNTY OF)
SWORN TO AND SUBSCRIBED before me this
_____ day of _____, 1994.

_____
NOTARY PUBLIC

[SEAL]

RANDY ROWLAND

DATE

STATE OF GEORGIA)
COUNTY OF)
SWORN TO AND SUBSCRIBED before me this
_____ day of _____, 1994.

NOTARY PUBLIC

[SEAL]

DUANPEI WU

DATE

STATE OF SOUTH CAROLINA)
COUNTY OF)
SWORN TO AND SUBSCRIBED before me this
_____ day of _____, 1994.

NOTARY PUBLIC

[SEAL]

Power of Attorney form.

Please forward all of the documents, except your checks of course, to Randy Rowland for his review prior to filing in the U.S. Patent and Trademark Office. As you are aware, this continuation-in-part application must be filed as soon as possible. Accordingly, please forward the documents to Randy Rowland immediately, so that we may file the application by October 20. Instruct Randy to overnight the entire package to me after he signs it. You might want to enclose a copy of this letter to Randy so that he will have the benefit of these instructions.

I would ask each of the inventors to cash the checks rather than hold them for keepsakes. Otherwise the accounting department will harass me about uncashed checks destroying the checkbook balance.

With best regards.

Sincerely,

DORITY & MANNING, P.A.

James M. Bagarazzi

JMB/lak
Enclosures: As stated
cc: Mr. Randy Rowland (Without Enclosures)
A:\CXU153.L4A

Applicant or Patentee: JOHN C. PECK, RANDY ROWLAND
DUANPEI WU
Attorney's Docket No.: CXU-153

Serial or Patent No.: Not yet assigned
Filed or Issued: Herewith
For: APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE

INDEPENDENT INVENTOR DECLARATION CLAIMING SMALL ENTITY STATUS UNDER 37 CFR §§ 1.9(f) and 1.27(b)

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE described in the specification filed herewith.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e)

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below: persons, concerns or organizations listed below

FULL NAME CLEMSON UNIVERSITY
ADDRESS Clemson, South Carolina 29634
[XX]NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

JOHN C. PECK	RANDY ROWLAND	DUANPEI WU
NAME OF INVENTOR	NAME OF INVENTOR	NAME OF INVENTOR
SIG.OF INVENTOR	SIG.OF INVENTOR	SIG. OF INVENTOR
DATE	DATE	DATE

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Carolyn B. Taylor

⑈021731⑈ ⑆053201607⑆ 516001223⑈

PATENT

ATTORNEY DOCKET NO.: CXU-153-CIP

UNITED STATES PATENT APPLICATION

of

JOHN C. PECK
and
DUANPEI WU
and
RANDY ROWLAND

for

APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE

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I hereby certify that this patent application is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the Date of Deposit indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

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(Typed or printed name of person mailing this application)

_____
(Signature of person mailing this application)

PATENT

ATTORNEY DOCKET NO.: CAR-1

TITLE OF THE INVENTION

APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE

BACKGROUND OF THE INVENTION

The invention described herein was developed pursuant to a contract with the Defense Logistics Agency, Contract Purchase Order No. DLA900-87-D-0017, and may be subject to rights and restrictions therein.

The present invention relates to apparel manufacture equipment and more particularly to that which is controlled by an operator's voice command.

This application is a continuation-in-part of copending United States Serial No. 08/155,100 filed November 19, 1993, which is fully incorporated by reference.

Apparel manufacture equipment includes, but is not limited to, devices such as sewing machines, embroidering machines, cutting machines, and the like. In the present state of the art, these machines are generally controlled by operators physically commanding the machine to perform some desired task or function. For instance, with regard to industrial or assembly-line type sewing machines, an operator controls the operations of the sewing machine through a foot pedal. The operator physically commands the sewing machine to perform a function by pressing his foot upon the pedal in a certain manner causing contacts within the pedal to make and/or break. These contacts in turn cause the sewing machine to respond in some desired manner.

The operator may also physically control the machine by manually operating relays, trips, and like control devices. This type of manual or physical control, especially in the case of the sewing machine with associated foot control pedal, contributes to operator fatigue and other physical ailments. For instance, a common complaint among operators using a foot control sewing machine while standing is

recurring lower back pain and leg problems. These ailments can be attributed to the fact that the operator must essentially balance himself upon one foot while maintaining control of the machine with the other foot over extended periods of time. Additionally, the operator in many instances must maintain his foot on the control pedal at a certain angle or tilt and with a certain amount of pressure to maintain the machine operating in a certain mode. This is an ergonomically unsound working condition and, in time could lead to serious health problems for the operators and financial hardships for the employer in the way of sick leave, insurance and disability payments, and the like. The present invention addresses these problems and provides an apparatus and method to overcome them.

OBJECTS AND SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide an apparatus wherein an operator controls specific operations of apparel manufacture equipment through verbal commands recognized by the equipment as distinct from other sounds in the environment and of the equipment.

A further object of the present invention is to provide an apparel manufacture system that recognizes and translates an operator's verbal command into a digital control signal that is recognized by and actable upon by apparel manufacture equipment, such as a sewing machine.

It is also an object of the present invention to provide improved apparatus and method for speech recognition control of sewing machines.

Another object of the present invention is to provide an apparatus and method for voice control of any variety of apparel manufacture equipment machines such as an embroidering machine.

Yet a further object of the present invention is to provide apparatus and method whereby an operator can control the operation of apparel manufacture equipment without the

use of hand or foot control devices.

A still further object of the present invention is to provide an ergonomically effective method and apparatus for controlling apparel manufacture equipment.

Still another object of the present invention is to provide a method and apparatus which allows a physically handicapped person to operate apparel manufacture equipment.

Still another object of this present invention is to provide an apparel manufacture system capable of discriminating speech patterns for a plurality of different operators and responding to one or more of the individual operators' specific speech patterns.

Yet another object of the present invention is to provide an apparel manufacture system capable of receiving a library of operator-specific voice reference patterns stored in an apparatus which can be downloaded into the apparel manufacture system prior to operating same.

It is also an object of the present invention to provide apparatus which can be retrofitted to existing apparel manufacture equipment to enable an operator to control specific operations of the apparel manufacture equipment through verbal commands recognized by the equipment as distinct from other sounds in the environment and of the equipment.

Still another object of the present invention is to provide apparatus for speech recognition control of apparel manufacture equipment capable of multi language/accent support.

And still another object of this invention is to provide an apparel manufacturing system capable of speech control from a portable personal sized battery powered speech recognition device.

It is an additional object of the present invention to provide an apparel manufacturing system capable of control from a portable personal sized speech recognition device

that requires no physical electrical connection with the manufacture equipment, thereby permitting an operator greater mobility and reducing the possibility of injury or property damage through entanglement with an electrical cord.

It is a still further object of the present invention to provide an apparel manufacture system capable of recording and storing the order and timing of a sequence of digital control signals and executing the control signal sequence, in the proper order and at the proper timing, in response to a single operator command.

It is another object of this invention to provide a self-tuning apparatus for speech recognition control of apparel manufacture equipment capable of recalibration in response to a changed ambient environment.

Additional objects and advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

To achieve the objects and in accordance with the purpose of the invention, as embodied and broadly described herein, apparatus for manufacturing apparel is provided wherein an operator controls specific operations of the apparatus through verbal commands recognized by the apparatus as distinct from other sounds in the environment of the apparatus. The apparatus of the present invention comprises means for performing an apparel manufacturing task; means for recognizing and translating a verbal command into a digital control signal; means for inputting an operator's verbal command into the recognizing and translating means; and interfacing means for presenting a digital control signal from the recognizing and translating

means to the apparel manufacturing task means in a form recognized and accepted by the apparel manufacturing task means, the interfacing means being in communication with the recognizing and translating means.

In one preferred embodiment of this invention, the interfacing means modifies the digital control signal into a form recognized and actable upon by the apparel manufacturing task means. In this embodiment, the interfacing means may comprise a conventional relay box or station. In another preferred embodiment, the digital control signal from the recognizing and translating means is already in a form recognized and accepted by the manufacturing task means. In this instance, the interfacing means routes the digital control signal to the apparel manufacturing task means without modifying the signal.

The recognizing and translating means according to the present invention preferably comprises a speech recognition computer. This speech recognition computer in turn preferably comprises means for creating a library of operator specific digitized voice reference patterns correlating to a set of specific control signals; means for storing the library of operator specific voice reference patterns; and means for accessing the control signal corresponding to the operator specific voice reference pattern that matches the operator's verbal command. In a most preferred embodiment of this invention, the speech recognition computer is relatively small and portable and can be worn by an operator, for instance, on his belt.

In yet another preferred embodiment of the present invention, the speech recognition computer communicates with the interfacing means through an infrared light linkage and identifies a specific manufacturing task means by including an identification code within the transmission therefrom.

In another preferred embodiment of the present invention, the apparatus further comprises means for

training the speech recognition computer to operate with a specific individual operator. This training means may comprise an external computer, such as a personal computer or hand-held computer, that is interfaceable, i.e., connected to communicate electrically, with the speech recognition computer. Alternatively, for example, the training means may be configured within the speech recognition computer. The training means is configured to allow an operator to communicate with and cause the speech recognition computer to create a library of operator-specific digitized voice reference patterns.

In still another preferred embodiment of the present invention, the speech recognition computer is configured such that, upon receiving a certain verbal command from the operator, the computer records the order and timing of the digital control signals corresponding to digitized voice reference patterns matching the operator's subsequent verbal commands and stores this sequential information in association with a preset voice reference pattern that has been recorded by the operator and stored by the computer. Subsequently, the computer will, upon matching the stored preset voice reference pattern to a verbal command from the operator, communicate the corresponding stored control signals to the manufacturing equipment in the order and timing of the recorded sequence.

Furthermore, in another preferred embodiment of this invention, the speech recognition computer is capable of self calibration. In this embodiment, the computer, upon receiving an instruction to recalibrate, prompts the operator to repeatedly issue verbal commands corresponding to certain stored voice reference patterns. By determining the variance between the prompted commands and the stored voice reference patterns, the computer adjusts certain parameters to permit more optimal operation in a changed sound environment.

Examples of such parameters include recognition threshold, delta score, and gain. In particular, the recognition threshold defines the degree of similarity between an operator's verbal command and a stored voice reference pattern required before the computer recognizes a match. The delta score defines the minimum difference between the similarity of an operator's verbal command to a first stored voice reference pattern and the similarity of the verbal command to any second stored voice reference pattern permitted before the computer recognizes a match between the verbal command and the first stored voice reference pattern. Adjustment of these parameters, and possibly the gain of incoming verbal commands, may permit a more optimal operation in an environment more noisy than that in which the computer was trained.

The apparel manufacturing task means of the present invention can be of any type of apparel manufacturing or sewing equipment. For example, in a preferred embodiment of the invention, the apparel manufacturing task means comprises a sewing machine. In another preferred embodiment, the manufacturing task means comprises an embroidering machine. Likewise, the manufacturing task means may comprise a clutch-type or cycle-type motor sewing machine.

In yet another preferred embodiment of the present invention, the apparel manufacturing task means further comprises an electric motor configured to control specific operational modes of the manufacturing task means. The electric motor has control circuitry that is compatible with the interfacing means and configured to receive and act upon digital control signals thereby directing the electric motor to perform a task according to an operator's verbal command. An example of this preferred embodiment would be a sewing machine with associated electric motor.

To further achieve the objects and in accordance with

the purpose of the invention, as embodied and broadly described herein, the method for voice control of apparel manufacture equipment according to the present invention comprises the steps of receiving an operator's verbal command; recognizing and translating the verbal command into a digital control signal; and routing the digital control signal to the apparel manufacture equipment.

In one preferred embodiment of the method of this invention, the routing step further includes modifying the digital control signal into a form recognized and actable upon by the apparel manufacture equipment.

Preferably, the recognizing and translating step further comprises the steps of inputting a verbal command to a speech recognition computer containing a library of operator specific digitized voice reference patterns correlating to an operator's verbal commands; searching the library of digitized voice reference patterns for a specific digitized voice reference pattern corresponding to the verbal command; and accessing and sending to the apparel manufacturing task means the specific digital control signal corresponding to said digitized voice reference pattern.

In still another preferred embodiment of this invention, the method further comprises the step of training the speech recognition computer to operate with a particular operator. This training may comprise interfacing a personal computer with the speech recognition computer to initiate and conduct the training.

In yet another preferred embodiment of this invention, the method further comprises the steps of recording the sequence, comprising order and timing, of a series of digital control signals retrieved by the computer and storing instructions, capable of executing said sequence, in association with a macro definition voice reference pattern and of selecting said digital control signal sequence upon matching the macro definition voice reference pattern with

an operator's verbal command.

In still another preferred embodiment of the present invention, the method further comprises the step of calibrating environment-dependent operating parameters, used in determining whether a stored voice reference pattern matches an operator's verbal command, in response to the operator's prompted verbal commands whereby said operating parameters are adjusted relative to a changed sound environment.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate various preferred embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the remainder of the specification, which makes reference to the appended Figs., in which:

Fig. 1 is a perspective view of a schematic illustration of an embodiment of the apparatus of the present invention.

Fig. 2 is a schematic representation of the embodiment of the invention shown in Fig. 1.

Fig. 3 is yet another schematic representation of the apparatus and method according to the present invention.

Fig. 4 is a schematic representation of another embodiment of the present invention.

Fig. 5 is a flow diagram of the method according to yet another embodiment of the present invention detailing a system calibration capability.

Fig. 6 is a flow diagram of the method according to still another embodiment of the present invention depicting a system macro capability.

Fig. 7a is a functional diagram of an infrared transmitter encompassed by yet another embodiment of the present invention wherein an infrared light linkage is employed.

Fig. 7b is a schematic representation of the infrared transmitter as in Fig. 7a.

Fig. 7c is a graphical representation of the modified Morse code signals transmitted by the infrared transmitter as in Figs. 7a and 7b.

Fig. 8a is a functional diagram of an infrared receiver encompassed by the embodiment of the present invention as in Figs. 7a, 7b, and 7c.

Fig. 8b is a state diagram depicting the decoding operation of the receiver as in Fig. 8a.

Fig. 8c is a schematic representation of the decoding circuit of the infrared receiver as in Fig. 8a.

Fig. 8d is a schematic representation of the clock generator as in the infrared receiver as in Fig. 8a.

Fig. 9 is a schematic representation of the infrared receiver and machine interface encompassed by the embodiment of the present invention as in Fig. 8a.

Repeat use of reference characters in the following specification and appended drawings is intended to represent the same or analogous features, elements, or steps of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the presently preferred embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described

as part of one embodiment, can be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modifications and variations as come within the scope of the appended claims and their equivalents.

A preferred embodiment of the present invention is shown in Figs. 1 and 2 (schematically) and generally designated by the numeral 10.

In accordance with the present invention, means are provided for performing a machine task such as an apparel manufacturing task. As embodied herein, an apparel manufacturing task means can include an apparel manufacture device or equipment capable of carrying out a desired task in the manufacture of apparel. Such tasks can include sewing, cutting, stitching, folding, pressing, stretching, or the like. Moreover, the use of the term "apparel" is not meant as a limitation of any sort upon the invention. The apparatus and method of this invention are not limited to clothing articles but include all products of the sewn products industry, for example curtains, seat covers, tents, sails, furniture upholstery and the like. Moreover, machine tasks other than apparel manufacturing could be adapted in accordance with the present invention.

As embodied herein and shown in Fig. 1 for example, one embodiment of a means for performing an apparel manufacturing task can include a sewing machine 12 which can sew two pieces of fabric together or attach thread 13 to a sheet of material. Sewing machine 12 may be of the clutch-type motor sewing machine, the cycle-type motor sewing machine, or an embroidering machine, but is not limited to these machines. The apparatuses and methods of the present invention are particularly suited for the field of apparel manufacture equipment that requires the skill and physical/manual control of an operator. Examples of such equipment include sewing machines, embroidering machines,

cutting machines, folding machines, pressing machines, stretching machines, and the like. The following description and appended drawings generally refer to the apparel manufacture equipment as a sewing machine 12, but this is for ease of illustration only and is not meant as a limitation. For example, the present invention could just as well be used for speech control of an embroidering machine or a cutting machine or a folding machine. Moreover, it is within the scope and spirit of the present invention to consider this apparatus and method in all applications of use where voice control of apparel manufacture equipment is desired.

In accordance with the present invention, means are provided for recognizing and translating an operator's verbal command into a digital control signal. As embodied herein and shown for example in Figs. 1-3, the recognizing and translating means preferably comprises a speech recognition computer 14. The speech recognition computer must be provided with means that converts sounds into electrical signals, which then can be received by computer 14 and converted into digital control signals that computer 14 sends via one of its output ports. In a most preferred embodiment of the present invention as depicted in Fig. 1, speech recognition computer 14 is relatively small and portable, capable of being carried by an operator, for example on his belt with belt loop 9, to a work station employing apparatus 10.

An example of a commercially available system which may be employed as speech recognition computer 14 is the MICRO INTROVOICE® by Voice Connexion. This system utilizes a NEC V-25 microcomputer operating at 8 megahertz. The system is a voice input/output system which provides speech recognition of 1,000 words with a published accuracy of better than 98%. The system includes system software for the control of recognition modes, training and updating,

vocabulary and voice pattern transfers, speech recognition, and word separability testing. The MICRO INTROVOICE® system is preferred for use in a factory environment because it can operate in noisy environments in excess of 85 db. In addition, there are a number of commercially available modular speech processing systems which may be used as speech recognition computer 14 in the present invention.

Implementation of some of the presently preferred embodiments of the present invention require, however, physical, software, and/or firmware enhancements or replacements of the commercially available systems such as the MICRO INTROVOICE® system. For example, an infrared light transmitter 100 may be constructed as an output port of speech recognition computer 14 as shown generally in Fig. 4. Additionally, software enhancements to implement self-tuning and macro capabilities, shown functionally in Figs. 5 and 6 respectively, require replacement or customization of the software and/or firmware associated with standard commercial systems such as the MICRO INTROVOICE®.

In further accordance with the present invention, inputting means are provided for inputting or receiving sounds, such as the sounds comprising an operator's verbal command, into the recognizing and translating means. As embodied herein and shown in Figs. 2 and 3 for example, such inputting means preferably comprises a microphone 20, which is electrically connected in communication with computer 14 via a cable 21. As shown in Fig. 1 for example, microphone 20 may be of the head-set type or throat type depending upon the operating environment of apparatus 10. For instance, a throat microphone may be more desirable in a noisy operating environment. Desirably, microphone 20 is provided with an electrical transducer which converts mechanical sound energy into electrical signals which constitute an electrical representation of the sounds of the voice commands. These electrical verbal commands, so-called, are transmitted to

computer 14 via cable 21. Desirably, when speech recognition computer 14 receives the electrical verbal commands from microphone 20, computer 14 converts them into digitized verbal commands. For example, computer 14 may be provided with an analog-to-digital converter for this purpose.

In an alternative preferred embodiment of this invention, the inputting means may comprise an area receiver, for example an area microphone mounted to a wall, or a desk top microphone. Desirably, the inputting means should be sensitive enough to pick up the operator's verbal commands and be in communication with speech recognition computer 14.

Desirably, as shown in Fig. 1 for example, microphone 20 forms part of a headset 22. Headset 22 allows an operator to maintain his hands free and moves with the operator's head. Headset 22 desirably includes a receiver 23 which forms part of the earpiece of headset 22. The voice synthesizer of computer 14 can be connected via cable 21 and receiver 23 to be heard by the operator wearing headset 22.

As embodied herein and schematically shown in Fig. 3 for example, speech recognition computer 14 preferably includes means for creating a library of operator-specific digitized voice reference patterns. In other words, in this library, a particular digitized voice reference pattern will be correlated to a particular digital control signal. In this way, as depicted in Fig. 3, an entire set of digital control signals will be made specific to the voice reference patterns of a particular operator or operators. Then, as explained below, upon matching a received digitized verbal command to a stored digitized voice reference pattern, computer 14 sends the corresponding digital control signal to an output port of computer 14. The library creating means allows an operator to create his own personal library

of voice reference patterns which are recognized and accepted as verbal commands by speech recognition computer 14. Essentially, the library creating means allows an operator to input a verbal signal into speech recognition computer 14 which in turn matches the operator's verbal command with the digitized voice reference pattern which is in turn associated with a digital control signal.

As embodied herein and schematically illustrated in Fig. 3 for example, speech recognition computer 14 further includes means for storing the library of operator-specific digitized voice reference patterns. In a preferred embodiment, the storing means consists of a memory device, such as a nonvolatile RAM, forming part of speech recognition computer 14. As schematically shown in Fig. 2 for example, these storing means allow the operator to download his library of voice reference patterns from an external memory device such as a personal computer 34 to speech recognition computer 14.

In a most preferred embodiment, the storing means comprises a nonvolatile memory within speech recognition computer 14. This allows for speech recognition computer 14 to be relatively small and portable. This arrangement is also preferred because it eliminates the necessity of the operator having to download his voice reference patterns to speech recognition computer 14 prior to each use of apparatus 10. The library of voice reference patterns would remain in the memory until another operator subsequently downloads his personal library to speech recognition computer 14.

In an alternative embodiment of this invention, speech recognition computer 14 can include a permanent type of memory (e.g., hard drive) system. In this alternative embodiment, the library of operator-specific voice reference patterns for all operators could be stored permanently within speech recognition computer 14. The operator could

then simply access his personal library from the hard drive and transfer the library to the operating storing means.

As depicted schematically in Fig. 3 for example, speech recognition computer 14 further comprises means for accessing operator-specific digitized voice reference patterns from the library. The accessing means selects from an operator's stored library of voice reference patterns, a particular voice reference pattern that corresponds to a specific verbal command inputted by the operator. The accessing means can include a preprogrammed microcomputer. This preprogrammed microcomputer gives speech recognition computer 14 the capabilities of recognition, vocabulary and voice pattern transfers, and word separability testing.

An example of the library creating means includes the Voice Utility Program (VUP) provided with the MICRO INTROVOICE® system as a basic voice system program. This program provides for vocabulary creation, editing, user training, testing, and maintenance. As has been described above and is described in more detail below, however, some presently preferred embodiments of this invention alternatively comprise customized programming in place of the VUP to enable expanded vocabulary capabilities.

An example of the storing means includes the 128Kb RAM memory in the MICRO INTROVOICE® system.

An example of the accessing means is a microprocessor preprogrammed as the system software of the MICRO INTROVOICE® system.

Referring to Figs. 1 and 3, in operation, an operator inputs a verbal command into speech recognition computer 14 via microphone 20. Preferably, the operator is wearing speech recognition computer 14 on his person, for example hanging from his belt by belt loop 9. Computer 14 digitizes the electrical verbal command received from microphone 20. The accessing means 30 performs a comparison between the digitized signal which represents the voice or speech

pattern of the verbal command, and each of the digitized voice reference patterns which form the library in the storing means 28 of computer 14. If the comparison performed by the accessing means yields one or more signals that test within one or more certain predetermined ranges of values, the accessing means deems the comparison to result in a match, which corresponds to the speech recognition computer recognizing the verbal command. For example, the signals resulting from the comparison may include a recognition threshold signal, a delta score signal, and a gain signal, each of which being more fully explained below. Upon recognizing the specific verbal command, computer 14 then selects from the library of stored voice reference patterns the digitized voice reference pattern corresponding to the verbal command and retrieves its associated control signal, sending said control signal to an output port of computer 14. This latter operation corresponds to the final step of the speech recognition computer recognizing and translating a voice command into a digital control signal.

Desirably, speech recognition computer 14 may also have the capability of voice synthesis. In that case, speech recognition computer 14 can include a voice synthesizer to communicate with the operator. This arrangement is desirable when the operator speaks a verbal command into microphone 20 but when the accessing means of speech recognition computer 14 carries out the comparison function, computer 14 is unable to find in the stored library a digitized voice reference pattern corresponding to the electronic signal of the operator's verbal command. Upon such occurrence, computer 14 is programmed to operate the voice synthesizer to communicate with the operator in a manner using the spoken word to inform the operator that the command spoken by the operator into microphone 20 was not recognized by computer 14. Then, the operator could re-input the verbal command until it is recognized by computer

14.

The voice synthesis capability is also employed in another presently preferred embodiment of the present invention the operation of which is detailed in Fig. 5. In this embodiment, speech recognition computer 14 has the capability to recalibrate itself in response to prompted verbal commands from the operator. Such recalibration is typically desired when the operator has trained speech recognition computer 14 in one location and then attempts to operate the system in another location having a greater degree of ambient noise, for example a shop floor. In such a situation, the ambient noise may cause speech recognition computer 14 to reject verbal commands it would otherwise have matched to voice reference patterns stored in the operator's library.

To accommodate for changed environmental conditions, speech recognition computer 14 of this presently preferred embodiment is capable of recalibrating environment-dependent operating parameters, such as recognition threshold and delta score. Specifically, recognition threshold defines the degree of similarity between the digitized verbal command and the stored digitized voice reference patterns required before speech recognition computer 14 recognizes a match. Delta score defines the minimum difference between the similarity of the digitized verbal command to a first stored digitized voice reference pattern and the similarity of the digitized verbal command to any second stored digitized voice reference pattern permitted before speech recognition computer 14 recognizes a match between the digitized verbal command and the first stored digitized voice reference pattern.

That is, upon receiving a verbal command from the operator, speech recognition computer 14 compares the digitized verbal command to each digitized voice reference pattern stored in the operator-specific library and

determines the variance between the verbal command and each voice reference pattern and whether the variance corresponding to any stored voice reference pattern falls within the recognition threshold. Before a voice reference pattern falling within this threshold and having the least variance can be deemed a match, however, there must be no other voice reference pattern, either within or without the recognition threshold, having a variance from the verbal command so low as to create an unacceptable likelihood of a mismatch. Thus the delta score is the minimum difference permitted between the variance associated with the candidate voice reference pattern and that associated with any other voice reference pattern permitted before speech recognition computer 14 recognizes a match between the verbal command and the candidate voice reference pattern.

Referring now to Fig. 5, a flow diagram of the recalibration routine of speech recognition computer 14 is shown. Generally, upon receiving the recalibration instruction from the operator, speech recognition computer 14 prompts the operator to repeatedly issue preselected verbal commands corresponding to certain or all of the voice reference patterns stored in the operator's library. By determining the variances at each repetition, speech computer 14 determines a representative variance for each voice reference pattern in the library. Based upon these representative variances, speech recognition computer 14 adjusts the recognition threshold and the delta score so that verbal commands having variances near the representative variances will be recognized as matches. Furthermore, the scope of the present invention incorporates the optimization of additional parameters, for example, the gain applied to received verbal commands.

More specifically, and again referring to Fig. 5, the operator issues a recalibrate instruction, in this preferred embodiment by means of a switch or button mounted on the

casing of speech recognition computer 14, at 50. If the computer is not at the final voice reference pattern to be prompted or the final prompt of a specific voice reference pattern at 52 and 54 respectively, speech recognition computer 14 prompts the operator at 56 for one of the stored voice reference patterns. After receiving and digitally converting the responsive verbal command at 58, the variance between the responsive verbal command and the voice reference pattern is determined at 60. When the final prompt is detected at 54 for the final voice reference pattern at 52, speech computer 14 adjusts the recognition threshold and delta score based on the representative variances as described above.

In a preferred embodiment of this invention, speech recognition computer 14 has the capability to process, store, and recognize word groups, not just single-word verbal commands. For example, the MICRO INTROVOICE® system can isolate word groups into separate sub-libraries within a single master library and up to 15 independent sub-libraries can be accessed at any time. This arrangement is preferred because it provides far greater flexibility in composing the library of verbal commands.

The present invention is not limited to any particular language or even to any use of spoken words in general. For example, the operator need not speak English when "training" speech recognition computer 14 to associate a sound with a digital control signal. In addition, any combination of sounds uttered by an operator can correspond to a digital control signal. In other words, an operator need not speak the word "stop" to command the apparel manufacture equipment to cease operating. Speech recognition computer 14 can be trained by the operator so that any distinct voice reference pattern will correlate to a specific control signal. The operator may choose voice reference patterns such as numbers or colors to correspond to a specific control signal which

causes the apparel manufacture equipment to stop, for example. The operator need not use the word "stop" as the command. For example, if the operator has trained speech recognition computer 14 to correlate spoken numbers to a particular digital control signal, then speech recognition computer 14 will only generate that control signal response to those particular spoken numbers matching the speech pattern of that particular operator.

In an alternative preferred embodiment of the present invention, speech recognition computer 14 is configured to be compatible with more than one operator while maintaining the capability of distinguishing between operators. Thus, apparatus 10 is not restricted to use with only one particular operator. Any operator can operate any apparel manufacture equipment by downloading his library of digitized voice reference patterns to the storing means of speech recognition computer 14. However, once a particular operator's library is downloaded to computer 14, then only that operator can operate the apparel manufacture equipment forming part of apparatus 10. Thus, apparatus 10 discriminates between operators while being compatible with any number of operators.

Speech recognition computer 14 also preferably maintains the capability to recognize words or commands in context. For instance, if an operator were using apparatus 10 in a factory environment and were to engage in a conversation, it would be undesirable to have computer 14 process every verbal word or sound that it picked up. The operator could place apparatus 10 in a standby or passive mode by inputting a verbal command, for example, the word "relax." Speech recognition computer 14 can be "trained" to put itself into a passive mode upon receiving a certain verbal command. This assumes that computer 14 had been programmed to translate the word "relax" to a control signal that puts apparatus 10 in a passive mode of operation.

Apparatus 10 would remain in that passive mode until receipt of another command, for example the spoken word "attention," which would have been preprogrammed to cause computer 14 to assume the active mode of operation. Thus, instead of sending a digital control signal to an output port upon receiving a particular voice command corresponding to the command to assume the passive mode, computer 14 would send itself a signal to suspend the accessing means from sending further control signals to the output port. It would then listen for another particular verbal command that would place it back into its active mode of sending its control signals to its output port. For example, the control program in the microprocessor NEC V-25 microcomputer in the MICRO INTROVOICE® system has such a capability.

In another presently preferred embodiment of the present invention, speech recognition computer 14 also preferably maintains a macro capability. That is, the computer, in response to the operator's command, records the order and timing of a series of verbal commands and executes the command sequence, in the proper order and at the proper timing, in response to a single operator command.

Regarding the macro capability, a procedure executed by the accessing means of speech recognition computer 14 is detailed in the flow chart depicted in Fig. 6. Upon receiving a verbal command at 70, speech recognition computer 14 matches the command to the library of stored voice reference patterns at 72. If at 74 the computer has matched the verbal command with the stored voice reference pattern that is the learn mode reference pattern, in this embodiment "learn," indicating that the macro capability should be activated, learn mode is activated at 76. The computer will then look at 78 for a verbal command matching one of the preset stored macro definition voice reference patterns. These specific voice reference patterns are stored in the operator specific library but are associated

with a macro memory position instead of a digital control signal. Thus, when the computer matches the verbal command at 78 to a macro definition voice reference pattern, memory is set to the appropriate macro memory position at 80 and the loop is exited at 82. Thereafter, computer 14 will record the order and timing of subsequent control signals corresponding to matched digitized voice reference patterns until receiving a command, in this embodiment "done," at 84 to deactivate the macro capability at 86.

If the learn mode is activated at 88, however, speech recognition computer 14 is already in learn mode and records the address, or position, of the digital control signal corresponding to the matched digitized voice reference pattern and the time between its selection and that of the prior digital control signal at 90 and communicates the control signal to the output port of computer 14 at 92. In this embodiment, the selected digital control signals are recorded. It is to be understood, however, that the digital voice reference patterns could also, or alternatively, be recorded without departing from the scope of the invention. Thus, by activating the macro capability, the operator creates a macro while executing a sequence of operations.

Once created, the operator may execute the macro by issuing a verbal command corresponding to one of the macro definition voice reference patterns. If the computer detects one of these macro definition voice reference patterns at 94, the appropriate control signal sequence is communicated, in the proper order and timing, to the computer's output port at 96.

In accordance with the present invention, interfacing means are provided for presenting, or routing, the digital control signal to the means for performing an apparel manufacturing task in a form recognized and accepted by the apparel manufacturing task means. Desirably, the interfacing means is connected in communication with the

recognizing and translating means. In one preferred embodiment of this invention shown in Figs. 1 and 2 for example, the interfacing means can include an electrical cable 18, which routes the digital control signal from an output port of speech recognition computer 14 to sewing machine 12 or another apparel manufacture equipment. In this embodiment, the control signal generated by speech recognition computer 14 already exists in a form recognized by and actable upon by sewing machine 12, the apparel manufacture equipment.

In another preferred embodiment of the invention shown schematically in Figs. 1 and 2 for example, the interfacing means may comprise a relay box or station 19 in addition to cable 18. Relay box 19 is configured to modify the digital control signal into a form recognized by and actable upon by the particular apparel manufacture equipment forming part of apparatus 10 of the present invention. For example, in the embodiment of the invention depicted in Figs. 1 and 2, speech recognition computer 14 may, for example, employ a RS-232 serial interface, as is used in the MICRO INTROVOICE system. Sewing machine 12 may not be capable of being actuated or controlled by RS-232 signals in serial form, hence relay station 19 is provided to modify the control signal into an appropriate collection of relay closures.

A conventional relay station can be used as relay box 19. Relay box 19 may, for example, include a relay station comprising a solid state logic circuit for converting a parallel TTL signal into appropriate relay signals.

In still another preferred embodiment of the present invention, the interfacing means is connected in communication with the recognizing and translating means by an infrared light linkage. This linkage obviates the need for cable 18, as depicted in Fig. 1, between speech recognition computer 14 and relay box 19, thereby allowing an operator greater freedom of movement and preventing

possible cable entanglements.

The infrared linkage is shown generally at Fig. 4, wherein a transmitter 100, mounted on speech recognition computer 14, communicates with a receiver 102, mounted on relay box 19. It should be understood, however, that such a configuration is by way of example only. For example, receiver 102 may be mounted on the underside of the table similarly to box 19 as shown in Fig. 1, and connected by a cable 18 to relay box 19. Furthermore, and in a presently preferred embodiment, transmitter 100 is constructed within the housing of speech recognition computer 14. It will be understood by those of ordinary skill in the art that all such equivalent physical configurations are within the scope of the present invention.

Transmitter 100 and receiver 102 are functionally depicted in Figs. 7a and 8a respectively. Referring to Fig. 7a, a digital output signal at data line 128 from speech recognition computer 14 is used to modulate a carrier by a modulator 104, which is regulated by a clock 106. The transmission rate is determined by speech recognition computer 14. The presently preferred embodiment as in Fig. 7a transmits at 1 Kbits per second. A driver 108 amplifies the resulting modulated signal to drive an infrared light emitting diode 110.

A physical embodiment of the transmitter as in Fig. 7a is depicted in Fig. 7b. Modulator 104 and driver 108 are embodied in a powered NAND gate 112. The inputs to NAND gate 112 are the data signal from speech recognition computer 14 and the 40 kHz oscillating signal from clock 106. In this embodiment, clock 106 is an Epson America SE3316 quartz crystal having a load capacitance of 11 pf and series resistance of 35 Kohms to 15 Kohms. The output from NAND gate 112 drives infrared light emitting diode 110 through a resistor 114, which in this embodiment is rated at 120 Ohms. In this embodiment, diode 110 is a Panasonic

LN64PA-ND having a peak emission wavelength of 950 nm and a 45 degree beam angle.

In operation, speech recognition computer 14 provides infrared transmitter 100 with a data signal. To prevent interference by environmental light noise, a modified Morse Code is employed as depicted in Fig. 7c. More particularly, data streams are generally configured as at 116. A reset signal is followed by a start bit followed by a message stream. Examples of reset and start signals employed in this presently preferred embodiment are depicted at 118 and 120, respectively, showing high and low signals generated by speech recognition computer 14.

In this present embodiment, the message stream is comprised of bits as represented at 122 and 124. As will be explained below, "zero" bits and "one" bits may have various representations as in 122 and 124 respectively. Finally, an example of a bit stream that could be employed by this presently preferred embodiment is shown at 126, comprising reset, start, one, zero, and one bits. It will be understood by those of ordinary skill in the art, however, that various coding schemes other than Morse code, for example a scheme employing cyclic codes, could be employed without departing from the scope and spirit of the present invention, and that the use of such schemes is encompassed by such scope and spirit.

Referring again to Fig. 7b, message streams as in Fig. 7c are input to NAND gate 112 at data line 128. Clock 106 comprises the second input. When the input at data line 128 provides a high signal, the output of NAND gate 112 oscillates at the clock frequency, causing no emission from infrared light emitting diode 110. When the input at data line 128 provides a low signal, the output of NAND gate 112 remains high, causing a pulse of equal duration to be emitted from diode 112.

Fig. 8a functionally depicts receiver 102. A

demodulator 130 is an infrared receiver/demodulator and in this embodiment is implemented by the integrated circuit GP1U52X, a commercially available and highly reliable hybrid infrared detector used with televisions, VCRs, audio components, and like equipment. The GP1U52X uses a pin photo diode that has its peak sensitivity at 980 nm. The internal filter blocks visible light to reduce or eliminate false operation caused by other light sources. The bandpass filter operates at 40kHz with a bandwidth of +/-4kHz.

A decoding circuit 140 is schematically indicated in Fig. 8a by the encircling dashed line. As shown in Fig. 8a, for example, a suitable decoding circuit 140 can be comprised of a finite state machine 132, a shift register and ID matching circuit 134, and a buffer 136. Finite state machine 132 is regulated by a clock 138. Generally, finite state machine 132 decodes the modified Morse Code signals from receiver/demodulator 130, outputting an internal clock signal 144 and an internal data signal 146 to shift register/ID matching circuit 134. At the end of each message stream, shift register/ID matching circuit 134 provides an "update" signal 148 to output buffer 136 if no error has occurred, and the control signal is then communicated to the interface device as described in more detail below.

In particular, a state diagram 142 for the finite state machine is shown in Fig. 8b. Those of ordinary skill in the art will recognize, however, that this state diagram and the corresponding circuit implementation depicted in Fig. 8d comprise one presently preferred embodiment. It is to be understood that various circuitry and decoding means may be employed and are within the scope of the present invention. Referring to Fig. 8b, six states with transition paths are indicated. The 1 or 0 above each transition path arrow indicates the high or low signal, respectively, of the modified Morse codes as in Fig. 7c that prompt the state

transition. In this embodiment, the state diagram is so constructed that a "one" bit or a "zero" bit as shown in Fig. 7c may have one or two trailing lows without affecting the device's operation. A falling clock pulse, represented by the "z" variable in Fig. 8b, at line 144 (Figs. 8a and 8c) causes shift register/ID matching circuit 134 (Fig. 8a and as schematically represented in Fig. 8c) to shift registers and to read the internal data, represented by the "y" variable in Fig. 8b, at line 146 (Figs. 8a and 8c). For example, a falling clock from state 2 to state 5 and an internal data bit of one at state 5 cause a one to be input to shift register/ID matching circuit 134.

Referring now to Fig. 8a, when 7 bits have been read, and the message ID matches the preset machine identification code, shift register/ID matching circuit 134 communicates an update signal to buffer 136 at 148, causing the four-bit control signal to be communicated to buffer 136 at 150. This signal will then control sewing machine 12 until replaced by another signal.

Referring now to Fig. 8c, the logic circuit implementation of decoder 140 is shown. In this presently preferred embodiment, the circuit is "burned" into a program logic circuit, for example an EPM5016 chip. This circuit implements state diagram 142 and the shift register of circuit 134 as discussed above. Additionally, the ID matching is now described in more detail.

The message signal read into the shift register is comprised of 7 bits comprised of a 4 bit control signal and a 3 bit identification code. The 4 bit control signal is communicated to sewing machine 12 at 152a, 152b, 152c, and 152d if the three bit matching signal matches the preset machine identification code set at inputs 154a, 154b, and 154c or if either a global identification code is received or set as the preset machine identification code. Specifically, if these bits, read from shift register 156,

match the preset identification number, the output of AND gate 158 goes high, updating buffer 136 as in Fig. 8a. The same result will occur, however, if receiver 102 receives the global identification code, in this embodiment a binary seven, which causes AND gate 160 to go high. Similarly, if the inputs 154a, 154b, and 154c are set to a binary seven, AND gate 162 goes high, updating the buffer.

Thus, in this presently preferred embodiment, an operator may access a machine by any of three methods. First, he may cause his transmitter to transmit the identification code of a particular desired machine with every control signal. In this embodiment, the operator sets the identification code during the training stage through the external computer 34 (Fig. 1). However, it is to be understood to be within the scope of the present invention to encompass any equivalent technique, such as setting the identification code by voice command or by switches linked to transmitter 100. Second, the operator may cause his transmitter to transmit the global identification code, causing every machine receiving the signal to respond to the command. Finally, he may preset the receiver at a particular machine to the global identification code, causing that machine to respond to every command it receives, regardless of the signal's corresponding identification signal. The method of presetting the machine according to the presently preferred embodiment is described in more detail below with regard to Fig. 9.

The clock generator 138 as shown in Fig. 8a is realized according to the presently preferred embodiment as shown in Fig. 8d. The clock generator 138 is comprised of a 4.096 MHz quartz crystal oscillator 164 and a 14 stage binary counter 166. The clock's operation is enabled at 168 by the "enable" output from finite state machine 132 as in Fig. 8a. When enabled, clock 138 generates a 1 KHz signal at 170. In the presently preferred embodiment, inverters 172 are

implemented by employing an integrated circuit device, for example an MM74HC00 or MM74HC04 chip. Similarly, binary counter 166 is implemented in this embodiment by an integrated circuit device such as a CD4060 or CD4020.

Referring now to Fig. 9, a circuit diagram of receiver 102, as represented within the dashed line so designated, and interface 19 according to this presently preferred embodiment is shown. Interface 19 is indicated by the components within the dashed line so designated. In this embodiment, a power source is schematically indicated by the components encircled by the dashed line designated 174. Power source 174 is employed to provide a 24V source to relays 178a, 178b, 178c, and 178d. Those of ordinary skill in the art will understand, however, that power source 174 will be unnecessary for some machines having an internal power source. Such machines will provide power internally to relays 178a-d through the circuitry of interface 19.

In operation, control signal output bits are communicated to interface 19 from receiver 102 by output lines 152a, 152b, 152c, and 152d to relays 178a, 178b, 178c, and 178d, which default to an off setting. For ease of explanation, because buffer 136 is included in the circuitry of decoder 140, buffer 136 is indicated as an element of receiver 102. Because its function is to store data and because some embodiments of the present invention may include such a buffer in an interface without an infrared linkage, however, buffer 136 may also be considered an element of interface 19. As shown in Fig. 9, relays 178a-d switch on or off, depending upon the signals on lines 152a-d, and provide either 24 volts or zero volts to pins D0, D1, D2, and D3 of connector 179, thereby controlling the operation of sewing machine 12. In this embodiment, five volt power sources 180 may be supplied by power source 174 at 182. Additionally, switches 184 are used to set the machine identification number on lines 154a, 154b, and 154c

as in Fig. 8c.

The above described implementation of infrared transmitter 100, receiver 102, and interface 19 depict but one presently preferred embodiment of the invention. Various equivalent electrical realizations, as will be well known in the art, could be achieved without departing from the scope of the present invention. Additionally, the electrical requirements of a particular machine to which the present invention is applied could require modifications. For example, in this embodiment, 24 volt and zero volt signals are provided to connector 179 as in Fig. 9, but it is understood that some machines may require different voltage levels.

In one preferred embodiment of this invention, a means can be provided for training the speech recognition computer to operate with a specific individual operator. The training means essentially comprises a temporary communication interface between the operator and the speech recognition computer, and allows the operator to train the computer to create the library of digitized voice reference patterns specific to that operator.

In a preferred embodiment of this invention, as shown in Figs. 1 and 2, the training means may comprise an external computer 34, which can be in the form of a personal computer or hand-held computer (not shown). When a new operator desires to use apparatus 10 to control apparel manufacture equipment, he must train speech recognition computer 14 to recognize his speech pattern and create the library of voice reference patterns particular to that operator. External computer 34 allows the operator to communicate with speech recognition computer 14 to accomplish this task. In this embodiment, the operator creates and edits a vocabulary or library of voice reference patterns on the personal computer for later downloading to speech recognition computer 14. This library can be stored

internal to external computer 34, in an installed hard drive for example as depicted in Fig. 3, or upon a memory device such as a floppy disk or computer card. In this arrangement, the training means, specifically external computer 34, further acts as a storage device for the voice reference patterns and control signals. The operator interfaces speech recognition computer 14 with external computer 34 to create the digitized voice reference patterns correlating to his verbal command signals. The signals are then stored in external computer 34 until that operator is ready to use apparatus 10. At that point, the operator again interfaces computer 34 with speech recognition computer 14 to download the library of digitized voice reference patterns to the storing means of speech recognition computer 14. Once that operation is complete, external computer 34 is no longer necessary and may be disconnected from speech recognition computer 14.

In another alternative embodiment of the invention, the training means may also be used to set certain operating parameters, such as gain control, of speech recognition computer 14.

As noted above, the operator need not create the library of digitized voice reference patterns every time he desires to use apparatus 10. The library of voice reference patterns can be stored in an outside or external memory device, for example the hard drive of external computer 34. In that case, the operator need only download the library to the memory in speech recognition computer 14, for example a nonvolatile RAM. With this embodiment, speech recognition computer 14 would not have its own "permanent" type memory (e.g., a hard drive), but weight, power, and size considerations would be reduced to allow for a smaller portable speech recognition computer 14.

In an alternative embodiment of the present invention, speech recognition computer 14 comprises its own permanent

operator-specific digitized voice reference patterns stored in its library. If the comparison results in a match, speech recognition computer 14 recognizes and accepts the speech pattern of the operator. Speech recognition computer 14 then accesses the particular digital control signal corresponding to the matched digitized voice reference pattern and sends it to its output port. The signal is transmitted from the output port through an interfacing means, in this embodiment cable 18, to an apparel manufacture equipment, in this embodiment sewing machine 12. If necessary, the interfacing means can further include relay box 19 to modify the control signal from speech recognition computer 14 into a form accepted by and actable upon by sewing machine 12. The control signal is routed via the interfacing means to control circuitry 44 of electric motor 42. Control circuitry 44 responds to the digital control signal by directing electric motor 42 to change its operational state and thereby causing sewing machine 12 to perform a desired function.

The present invention provides an apparatus and method whereby an operator can control various functions of the apparel manufacture equipment by simply speaking a verbal command into the apparatus of the present invention, which translates the verbal command into a digital control signal and passes this signal to the apparel manufacture equipment in a form that is recognized by the equipment. The equipment then responds to this signal and performs the desired task. The voice control apparatus of this invention interfaces between the operator and the equipment without imposing any physical restraints or requirements upon the operator as a prerequisite to being able to operate and control the equipment. The operator is free to assume any stance or posture with which he is comfortable. Providing for this degree of physical mobility will prove extremely beneficial to both the operators and their employers.

Additionally, the present invention also allows one operator to control the operation of more than one type of machine. Presently, the general rule is that one operator works with one type of machine only since, as discussed above, that operator must be trained to physically or manually control the operation of the machine. The present invention provides means for an operator to communicate with any number of machines by simply inputting a voice command to those machines. Thus, it is feasible that far fewer employees will be needed to operate and control a far greater number of machines.

Also, the present invention requires very little in the way of physical skill, coordination, or aptitude from an operator. For example, a physically disabled person (for instance a wheelchair-bound person) could be employed to operate a voice controlled apparel manufacture device according to this invention; whereas previously such a person would be unable to function at this position. As long as a person could visually observe the operation of the machine and be able to speak verbal commands to control the machine, such a person would be a productive employee.

Also, the voice control method of this invention may reduce the amount of training needed by employees. A new employee could be trained in a relatively short time period. The employee need only learn the proper verbal commands and how to train the machine to accept his commands.

The present invention addresses the ergonomic related physical problems caused by the conventional apparel manufacture control methods and also provides apparatus and method allowing a far less skilled employee (both mentally and physically) to contribute as productive employees in this industry.

WHAT IS CLAIMED IS:

1. Apparel manufacturing system wherein an operator controls specific operations of an apparel manufacturing machine through verbal commands recognized by the system as distinct from other sounds in the environment of the system, the system comprising:

an apparel manufacturing device;

a recognizing and translating device, said recognizing and translating device configured to recognize the verbal command of the operator and to translate the verbal command into a digital control signal wherein said digital control signal includes an identification code corresponding to said apparel manufacturing device;

an input device, said input device being configured to input an operator's verbal command into said recognizing and translating device;

an interface device configured for presenting a digital control signal received from said recognizing and translating device to said apparel manufacturing device in a form recognized and accepted by said apparel manufacturing device; and

an infrared light linkage configured for connecting said interface device in communication with said recognizing and translating device.

2. System as in claim 1, wherein said recognizing and translating device comprises a speech recognition computer.

3. System as in claim 2, wherein said speech recognition computer further comprises:

means for creating a library of operator-specific digitized voice reference patterns correlating to a set of specific digital control signals;

means for storing said library of operator-specific digitized voice reference patterns; and

means for comparing an operator's verbal command with said library of stored digitized voice reference patterns and for accessing the digital control signal corresponding to the stored digitized voice reference pattern matching the operator's specific verbal command, said comparing and accessing means being connected in communication with said storing means and said interface device.

4. System as in claim 3, wherein said speech recognition computer is configured to recognize an individual operator's speech pattern and respond to that individual's speech pattern.

5. System as in claim 3 further comprising means for training said speech recognition computer to operate with a specific individual operator.

6. System as in claim 5, wherein said means for training comprises an external computer interfaceable with said speech recognition computer, said external computer being configured to allow the operator to communicate with and train said speech recognition computer to create said library of operator-specific digitized voice reference patterns.

7. System as in claim 1, wherein said apparel manufacturing device further comprises an electric motor configured to control specific operational modes of said apparel manufacturing device, said electric motor having control circuitry mateable with said interface device and being configured to receive and act upon said digital control signal thereby directing said electric motor to perform a task according to an operator's verbal command.

8. A speech recognition controlled sewing system, wherein an operator controls specific operations performable by said sewing system through verbal commands recognized by said sewing system as distinct from other sounds in the environment of said sewing system, comprising:

a sewing machine capable of performing a desired sewing task;

an electric motor connected to power the operation of said sewing machine;

electric motor control circuitry connected to said electric motor for controlling the operation of said electric motor;

a speech recognition computer for recognizing and translating a verbal command into a digital control signal accepted by and actable upon by said electric motor control circuitry wherein said digital control signal includes an identification code corresponding to at least said sewing machine, said speech recognition computer further comprising:

means for creating a library of operator-specific digitized voice reference patterns correlating to a set of specific digital control signals;

means for storing said library of operator-specific digitized voice reference patterns; and

means for comparing an operator's verbal command with said library of stored digitized voice reference

patterns and for accessing the digital control signal corresponding to the stored digitized voice reference pattern matching said operator's specific verbal command, said comparing and accessing means being connected in communication with said storing means and said electric motor control circuitry;

a microphone for inputting an operator's verbal command into said speech recognition computer;

an interface device for presenting the digital control signal to said electric motor control circuitry, said interface device being configured to connect said speech recognition computer into communication with and said electric motor control circuitry; and

an infrared light linkage configured to connect said interface device in communication with said speech recognition computer.

9. Control apparatus for operating at least one apparel manufacturing machine having machine control circuitry for controlling specific machine operations wherein an operator controls specific machine operations through verbal commands recognized by the control apparatus as distinct from other sounds in the environment of the machine, said control apparatus comprising:

a receiver for receiving an operator's verbal command and converting said verbal command into an electronic verbal command;

means for digitizing said electronic verbal command;

means for comparing said digitized verbal command to a library of stored operator specific digitized voice reference patterns and macro definition voice reference patterns and for retrieving one of a digital control signal and a control signal sequence corresponding to one of a stored digitized voice reference pattern and a macro definition voice reference pattern, respectively, matching said digitized verbal command whereby only a particular operator whose digitized verbal command matches said stored digitized voice reference patterns can operate the at least one apparel manufacturing machine; and

an interface device operably disposed between the machine control circuitry and said comparing and retrieving means, said interface device being configured to translate said digital control signals into signals recognized by the machine control circuitry for controlling the at least one operation of the apparel manufacturing machine.

10. Apparatus as in claim 9, further comprising means for recording the sequence, comprising order and timing, of a series of digitized voice reference patterns selected by said comparing and retrieving means and storing instructions capable of executing said sequence in association with a macro definition voice reference pattern.

11. Apparatus as in claim 9, further comprising means for recording the sequence, comprising order and timing, of a series of digital control signals selected by said comparing and retrieving means and storing instructions capable of executing said sequence in association with a macro definition voice reference pattern.

12. Apparatus as in claim 10, wherein said comparing and retrieving means is configured to select said digitized voice reference pattern sequence upon matching said macro definition voice reference pattern to said digitized verbal command.

13. Apparatus as in claim 11, wherein said comparing and retrieving means is configured to select said digital control signal sequence upon matching said macro definition voice reference pattern to said digitized verbal command.

14. Apparatus as in claim 9, wherein said digitizing means and said comparing and retrieving means comprise a speech recognition computer.

15. Apparatus as in claim 14, further comprising: a storage medium for storing said library, and means for interfacing with said speech recognition computer to create said stored library of operator specific digitized voice reference patterns and macro definition voice reference patterns.

16. Apparatus as in claim 15, wherein said interfacing means comprises an external computer interfaceable with said speech recognition computer, said external computer being configured to allow the operator to communicate with and train said speech recognition computer to create said library of operator specific digitized voice reference patterns and macro definition voice reference patterns.

17. Control apparatus for operating at least one apparel manufacturing machines having machine control circuitry for controlling specific machine operations wherein an operator controls specific machine operations through verbal commands recognized by the control apparatus as distinct from other sounds in the environment of the machine, said control apparatus comprising:

a receiver for receiving an operator's verbal command and converting said verbal command into an electronic verbal command;

means for digitizing said electronic verbal command;

means for comparing said digitized verbal command to a library of stored operator specific digitized voice reference patterns and for retrieving the digital control signal corresponding to a stored digitized voice reference pattern matching said digitized verbal command whereby only a particular operator whose digitized verbal command matches said stored digitized voice reference patterns can operate said at least one apparel manufacturing machine; and

means for calibrating at least one environment-dependent operating parameter of the control apparatus in response to an operator's prompted verbal commands.

22. Apparatus as in claim 17 wherein at least one said parameter comprises a delta score defining the minimum difference between the similarity of said digitized verbal command to a first stored digitized voice reference pattern and the similarity of said digitized verbal command to any second stored digitized voice reference pattern permitted before said comparing and retrieving means recognizes a match between said digitized verbal command and said first stored digitized voice reference pattern.

23. Apparatus as in claim 17 wherein at least one said parameter comprises the gain applied to said digitized verbal command.

24. Apparatus as in claim 17, wherein said digitizing means and said comparing and retrieving means comprise a speech recognition computer.

25. A speech recognition controlled apparel manufacturing system, wherein an operator controls specific operations performable by an apparel manufacturing machine through verbal commands recognized by said apparel manufacturing machine as distinct from other sounds in the environment of the apparel manufacturing machine, comprising:

an apparel manufacturing machine capable of performing a desired apparel manufacturing task;

a motor configured to power the operation of said apparel manufacturing machine;

motor control circuitry connected to said motor and configured to control the operation of said motor;

a speech recognition computer for recognizing and translating a verbal command into one of a digital control signal, a digital control signal sequence, and a digitized learn mode reference pattern, each of said digital control

signals being configured to be accepted by and actable upon by said motor control circuitry wherein each said digital control signal additionally comprises an identification code corresponding to certain said apparel manufacturing machines, said speech recognition computer further comprising:

means for creating a library of operator-specific digital voice reference patterns corresponding to a set of digital control signals and macro definition voice reference patterns corresponding to a macro memory position,

means for storing said library of operator-specific digital voice reference patterns and macro definition voice reference patterns,

means for comparing an operator's verbal command with said library of stored digitized voice reference patterns and macro definition voice reference patterns and for accessing one of a said digital control signal and a said digital control signal sequence corresponding to one of a said stored digitized voice reference pattern and a said macro definition voice reference pattern, respectively, matching the operator's specific verbal command,

means for recording the sequence, comprising order and timing, of a series of digital control signals selected by said speech recognition computer and storing instructions capable of executing said sequence in association with said macro definition voice reference pattern and whereby said speech recognition computer is capable of selecting said digital control signal sequence upon matching said macro definition voice reference pattern to said digitized voice reference pattern, and

means for calibrating environment-dependent operating parameters, used in matching the operator's

verbal commands to said stored digitized voice reference patterns, in response to the operator's prompted verbal commands to accommodate changed ambient environments;

a microphone for inputting the operator's verbal command into said speech recognition computer;

an interface device for presenting a control signal, corresponding to said digital control signal, to said electric motor control circuitry, said interface device being connected in communication with said electric motor control circuitry; and

an infrared light linkage for connecting said interface device in communication with said speech recognition computer.

26. The speech recognition controlled apparel manufacturing system as in claim 25, wherein said calibrating means is configured to elicit a response from said operator in the form of at least one preselected verbal command corresponding to a preselected digitized voice reference pattern and bases parameter calibration upon the variance between the operator's digitized verbal command corresponding to said elicited verbal command and said preselected digitized voice reference pattern.

27. A method for voice control of apparel manufacturing equipment, said method comprising the steps of:

creating and storing a library of operator specific digitized voice reference patterns;

receiving an operator's verbal command;

translating said verbal command into a digitized verbal command;

comparing the digitized verbal command to said library of operator specific digitized voice reference patterns;

retrieving the digital control signal corresponding to the digitized voice reference pattern matching the digitized verbal command; and

employing an infrared light linkage to route the digital control signal to said apparel manufacturing equipment.

28. The method as in claim 27, further comprising the step of using an interfacing device disposed between said infrared light linkage and said apparel manufacturing equipment to modify said digital control signal into a form recognized and actable upon by said apparel manufacturing equipment.

29. A method for voice control of apparel manufacturing equipment, said method comprising the steps of:

creating and storing a library of operator specific digitized voice reference patterns and macro definition voice reference patterns;

receiving an operator's verbal command;

translating said verbal command into a digitized verbal command;

comparing the digitized verbal command to said library of operator specific digitized voice reference patterns and macro definition voice reference patterns;

retrieving one of a digital control signal and a digital control signal sequence corresponding to the one of a said digitized voice reference pattern and a said macro definition voice reference pattern matching said digitized verbal command; and

routing said one of a digital control signal and a control signal sequence to the apparel manufacturing equipment.

30. The method as in claim 29, further comprising the steps of recording the sequence, comprising order and timing, of a series of digitized voice reference patterns corresponding to said retrieved digitized reference patterns and storing instructions, capable of executing said sequence, in association with said macro definition voice reference pattern.

31. The method as in claim 29, further comprising the steps of recording the sequence, comprising order and timing, of a series of said retrieved digital control signals and storing instructions, capable of executing said sequence, in association with said macro definition voice reference pattern.

32. The method as in claim 29, further comprising the step of selecting said digital control signal sequence upon matching said macro definition voice reference pattern to said digitized verbal command.

33. A method for voice control of apparel manufacturing equipment, said method comprising the steps of:

creating and storing a library of operator specific digitized voice reference patterns corresponding to respective different digital control signals;

receiving an operator's verbal command;

translating said verbal command into a digitized verbal command;

comparing said digitized verbal command to said library of operator specific digitized voice reference patterns;

retrieving from said library a digital control signal corresponding to the digitized voice reference pattern matching said digitized verbal command;

calibrating at least one environment-dependent operating parameter, used in matching said digitized voice reference patterns to said digitized verbal commands, in response to an operator's elicited verbal commands whereby said at least one operating parameter is adjusted relative to a changed ambient environment; and

routing said retrieved digital control signal to said apparel manufacturing equipment.

34. The method as in claim 33, wherein said operator initiates said calibration step.

35. The method as in claim 33, further comprising the step of eliciting a response from said operator in the form of at least one preselected verbal command corresponding to a preselected digitized voice reference pattern and basing parameter calibration upon the variance between the operator's digitized verbal command corresponding to said elicited verbal command and said preselected digitized voice reference pattern.

36. The method as in claim 33, wherein at least one said parameter comprises a recognition threshold defining the degree of similarity between said digitized verbal command and said stored digitized voice reference pattern required before said comparing and retrieving means recognizes a match.

37. The method as in claim 33 wherein at least one said parameter comprises a delta score defining the minimum difference between the similarity of said digitized verbal command to a first stored digitized voice reference pattern and the similarity of said digitized verbal command to any second stored digitized voice reference pattern permitted before said comparing and retrieving means recognizes a match between said digitized verbal command and said first stored digitized voice reference pattern.

38. The method as in claim 33, wherein at least one said parameter comprises the gain applied to said digitized verbal command.

39. A method for voice control of apparel manufacturing equipment, said method comprising the steps of:

creating and storing a library of operator specific digitized voice reference patterns corresponding to respective different digital control signals and macro definition voice reference patterns corresponding to respective different macro memory positions;

receiving an operator's verbal command;

translating said verbal command into a digitized verbal command;

matching said digitized verbal command to one of a said operator specific digitized voice reference pattern and a said macro definition voice reference pattern stored in said library;

retrieving from said library one of a said digital control signal and a control signal sequence corresponding to said matching one of a said digitized voice reference pattern and a said macro definition voice reference pattern, wherein digital control signal sequences are stored in association with corresponding macro definition voice reference patterns and wherein a specific digital control signal sequence is selected upon matching one of said macro definition voice reference patterns to said digitized verbal command;

calibrating environment-dependent operating parameters, used in matching said digitized voice reference patterns to said digitized verbal commands, in response to an operator's elicited verbal commands whereby said operating parameters are adjusted relative to a changed ambient environment and wherein the operator is prompted to repeat certain of said verbal commands corresponding to stored digitized voice reference patterns and wherein said calibration is based upon the variance between the operator's responsive digitized verbal commands and corresponding said stored digitized voice reference patterns;

employing an infrared light linkage to route said digital control signal to the apparel manufacturing equipment; and

modifying said digital control signal into a form recognized and actable upon by the apparel manufacturing equipment by means of an interfacing device configured to communicate between said infrared linkage and the apparel manufacturing equipment.

40. The method as in claim 39 further comprising the steps of recording the sequence, comprising order and timing, of a series of said retrieved digital control signals and storing instructions capable of executing said sequence in association with said macro definition voice reference pattern.

41. Apparatus as in claim 10, wherein said recording means is activated upon the matching by said comparing means of said operator's verbal command to a digitized learn mode reference pattern stored in said library.

42. The method as in claim 40, wherein said recording step is initiated upon matching said digitized verbal command to a digitized learn mode reference pattern stored in said library.

43. The system as in claim 5, wherein said speech recognition computer comprises said training means, said training means being configured to allow the operator to communicate with and train said speech recognition computer to create and edit said library of operator-specific voice reference patterns.

44. The apparatus as in claim 15, wherein said speech recognition computer comprises said interfacing means, said interfacing means being configured to allow the operator to communicate with and train said speech recognition computer to create and edit said library of operator-specific voice reference patterns and macro definition voice reference patterns.

45. The system as in claim 8, wherein said speech recognition computer further comprises a means for editing said library of operator-specific voice reference patterns and macro definition voice reference patterns.

46. The system as in claim 25, wherein said speech recognition computer further comprises a means for editing said library of operator-specific voice reference patterns and macro definition voice reference patterns.

ABSTRACT OF THE DISCLOSURE

Apparatus and method for speech recognition control of apparel manufacture equipment, such as a sewing machine, is provided. This invention allows an operator to control specific operational modes of the apparel manufacture equipment through verbal commands recognized by the equipment as distinct from other sounds in the environment of the equipment. The invention includes a device for recognizing and translating an operator's verbal command into a digital control signal; a communication device such as a microphone for inputting the operator's verbal command into the recognizing and translating device; and interfacing means for presenting the digital control signal to the apparel manufacture equipment in a form recognized and accepted by the equipment. The method for voice control of apparel manufacture equipment according to the present invention comprises the steps of receiving an operator's verbal command through, for instance, a microphone; recognizing and translating the verbal command into a digital control signal; and routing this digital control signal to the apparel manufacture equipment in a form recognized by an actable upon by the equipment. Various embodiments of the present invention are presented. For example, in one embodiment, an infrared light linkage is employed to transmit commands from an operator to the machine's control circuitry. Additionally, in another embodiment, the operator may record control signal macros, permitting the execution of a series of commands in a prerecorded order and timing upon the issuance of a single voice command. Furthermore, in yet another embodiment, the recognizing and translating device is capable of recalibration in response to the operator's prompted responses.

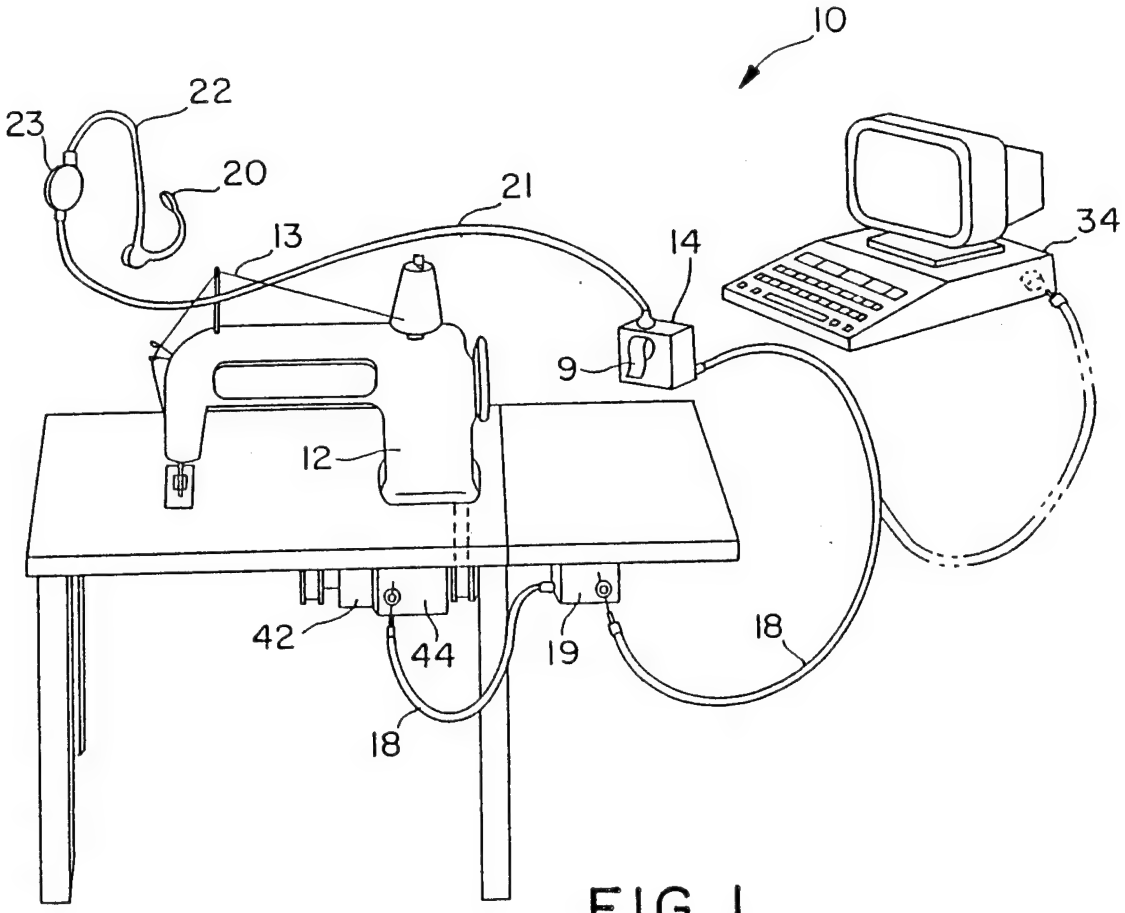

10
22
23
20
21
13
14
34
9
12
42
44
19
18
18

FIG. 1

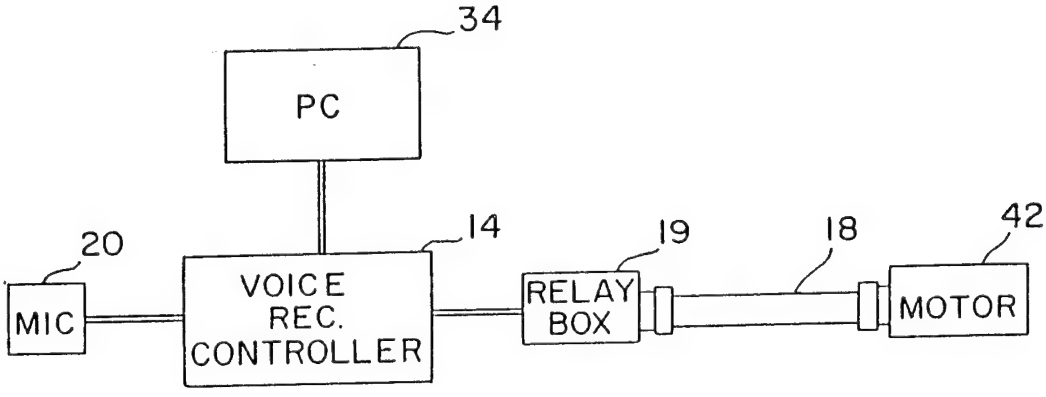

34
PC
20
14
19
18
42
MIC
VOICE
REC.
CONTROLLER
RELAY
BOX
MOTOR

FIG. 2

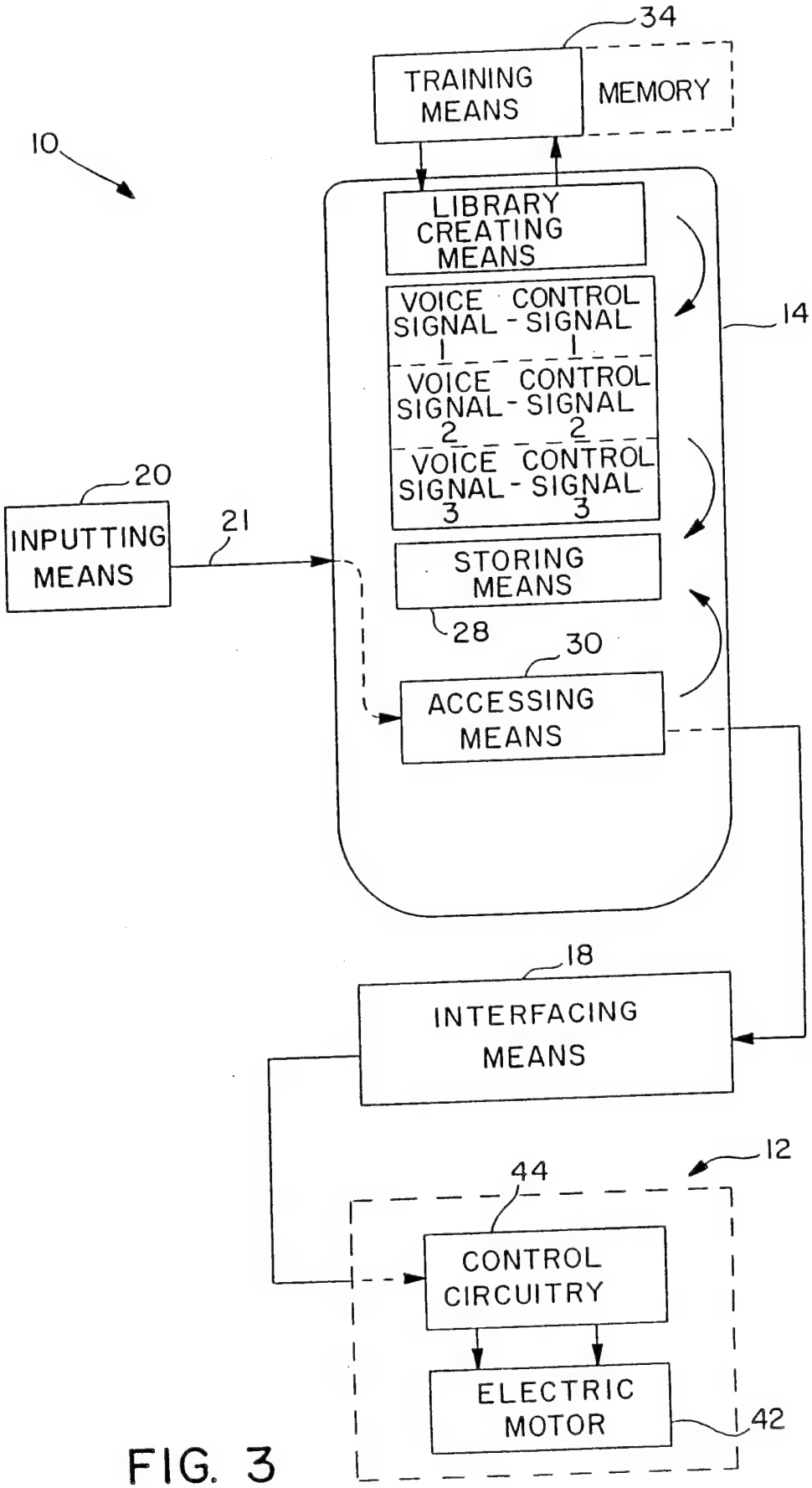

34
TRAINING MEANS
MEMORY
10
LIBRARY CREATING MEANS
VOICE SIGNAL 1
CONTROL SIGNAL 1
VOICE SIGNAL 2
CONTROL SIGNAL 2
VOICE SIGNAL 3
CONTROL SIGNAL 3
14
20
INPUTTING MEANS
21
STORING MEANS
28
30
ACCESSING MEANS
18
INTERFACING MEANS
12
44
CONTROL CIRCUITRY
ELECTRIC MOTOR
42

FIG. 3

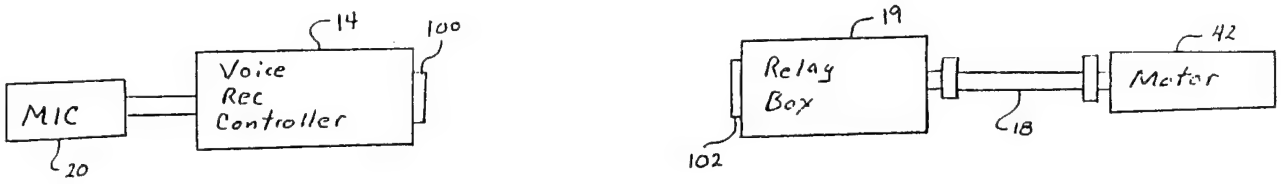

14
100
Voice
Rec
Controller
MIC
20
19
42
Relay
Box
Motor
18
102

FIG 4

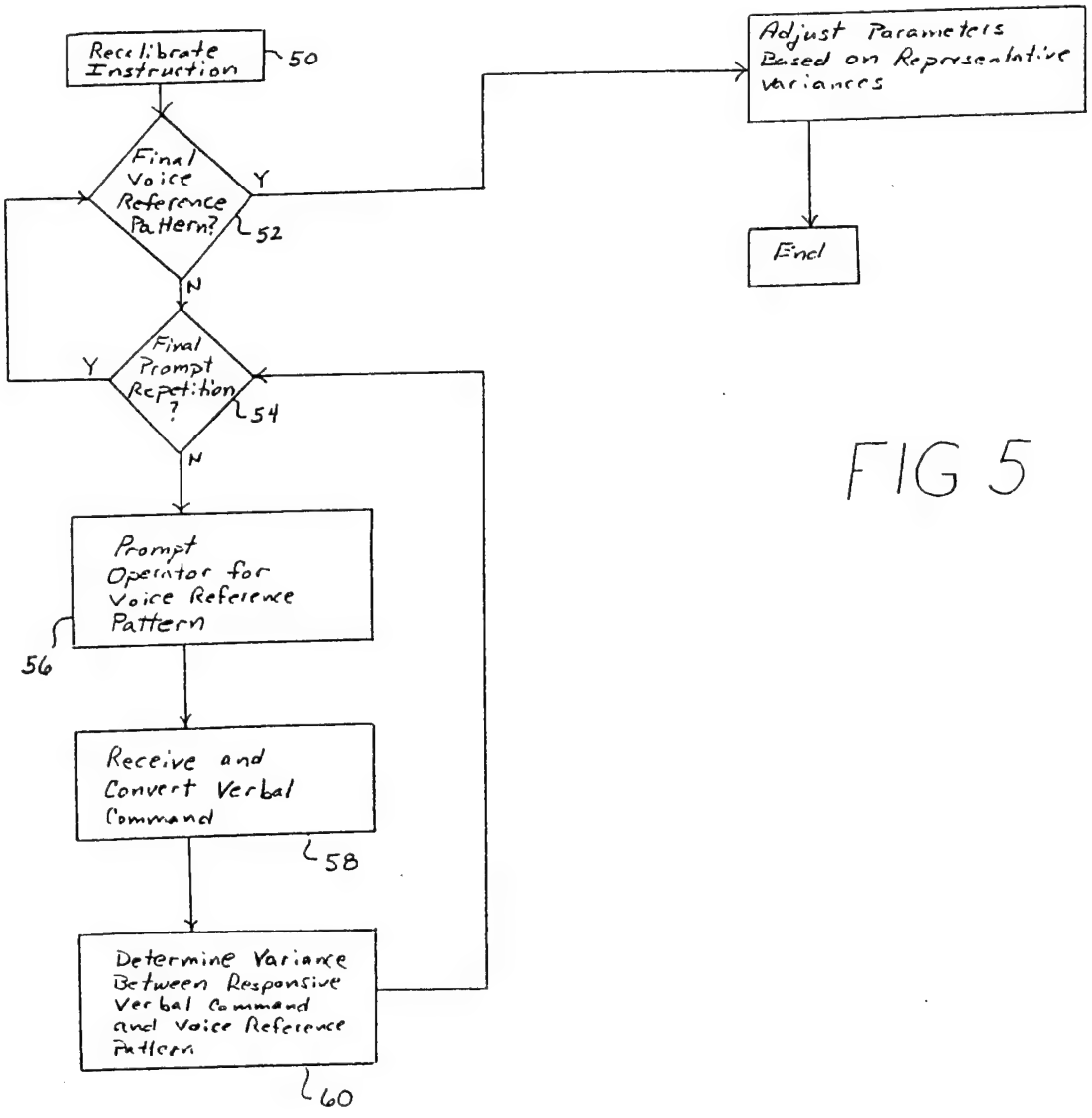

Recalibrate
Instruction
50
Final
Voice
Reference
Pattern?
52
Y
N
Final
Prompt
Repetition
?
54
Y
N
Prompt
Operator for
Voice Reference
Pattern
56
Receive and
Convert Verbal
Command
58
Determine Variance
Between Responsive
Verbal Command
and Voice Reference
Pattern
60
Adjust Parameters
Based on Representative
variances
End

FIG 5

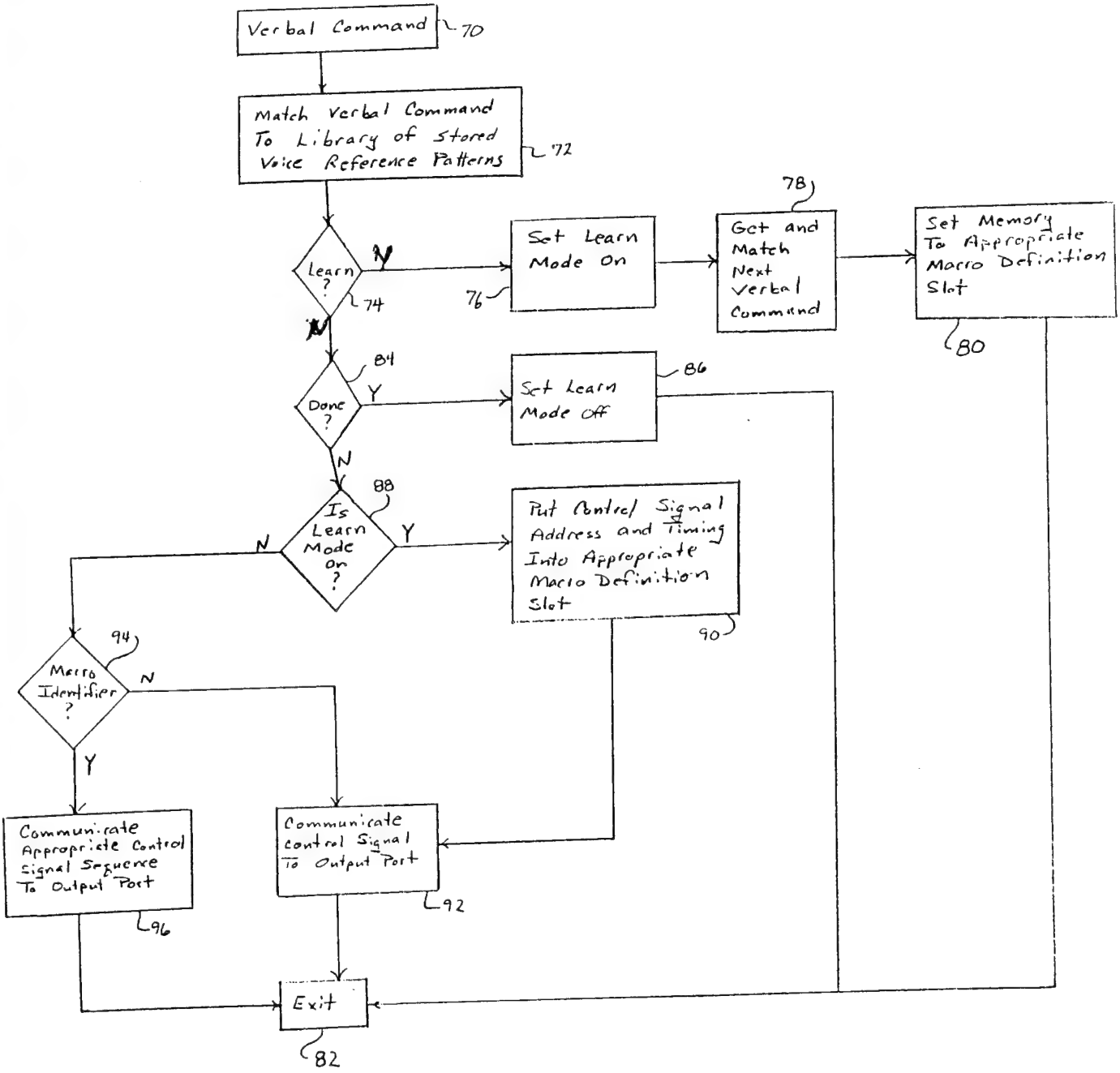

Verbal Command
70
Match Verbal Command To Library of Stored Voice Reference Patterns
72
Learn ?
74
Y
N
Set Learn Mode On
76
78
Get and Match Next Verbal Command
Set Memory To Appropriate Macro Definition Slot
80
Done ?
84
Y
N
Set Learn Mode Off
86
Is Learn Mode on ?
88
Y
N
Put Control Signal Address and Timing Into Appropriate Macro Definition Slot
90
Macro Identifier ?
94
Y
N
Communicate Appropriate Control Signal Sequence To Output Port
96
Communicate control Signal To Output Port
92
Exit
82

FIG. 6

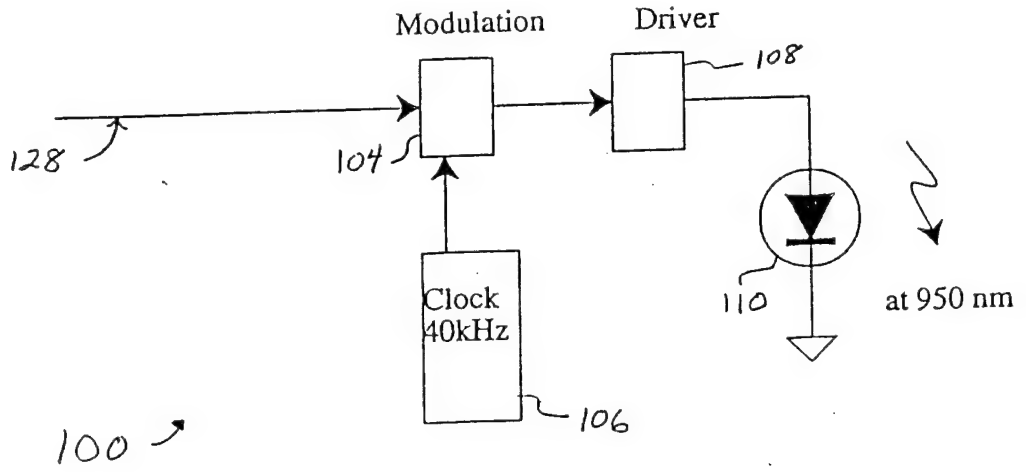

Modulation
Driver
108
128
104
Clock
40kHz
106
110
at 950 nm
100

FIG. 7a

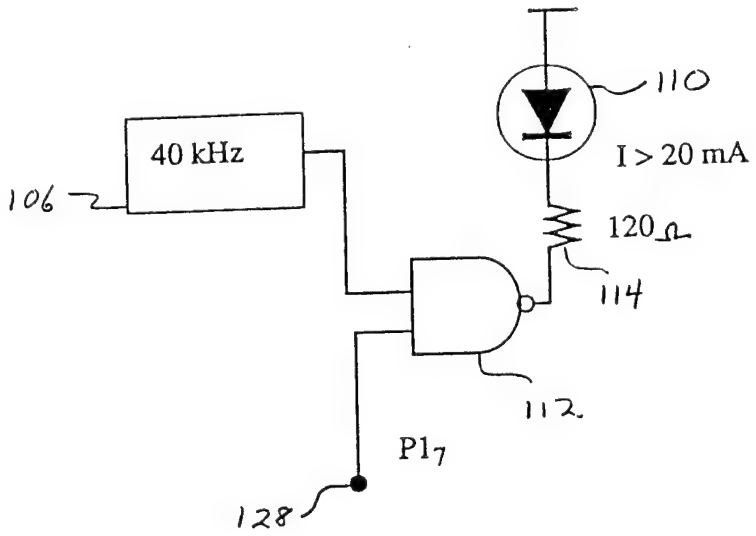

110
40 kHz
I > 20 mA
106
120Ω
114
112
P1.7
128

FIG. 7b

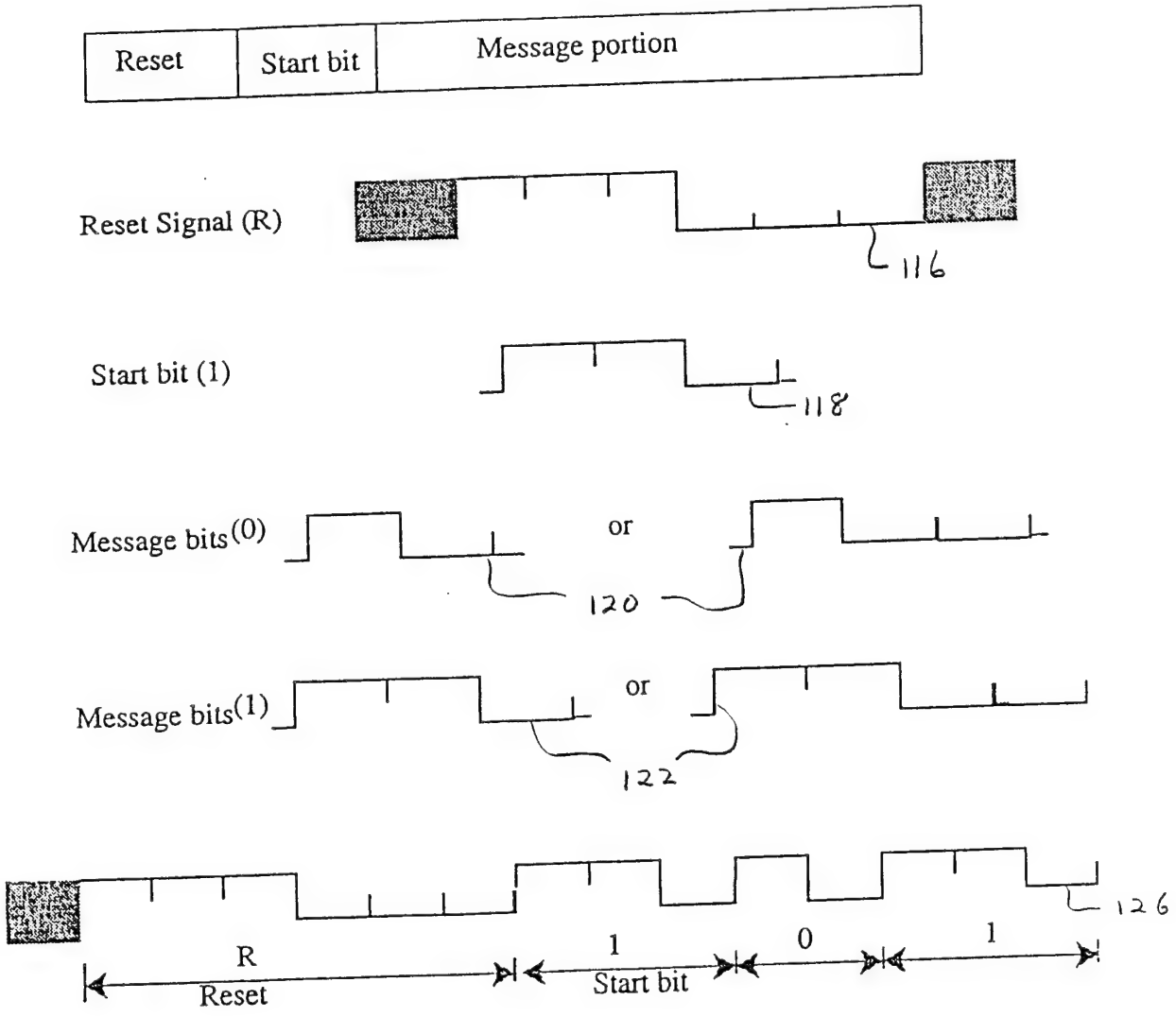

Reset
Start bit
Message portion
Reset Signal (R)
116
Start bit (1)
118
Message bits(0)
or
120
Message bits(1)
or
122
126
R
Reset
1
Start bit
0
1

FIG. 7c

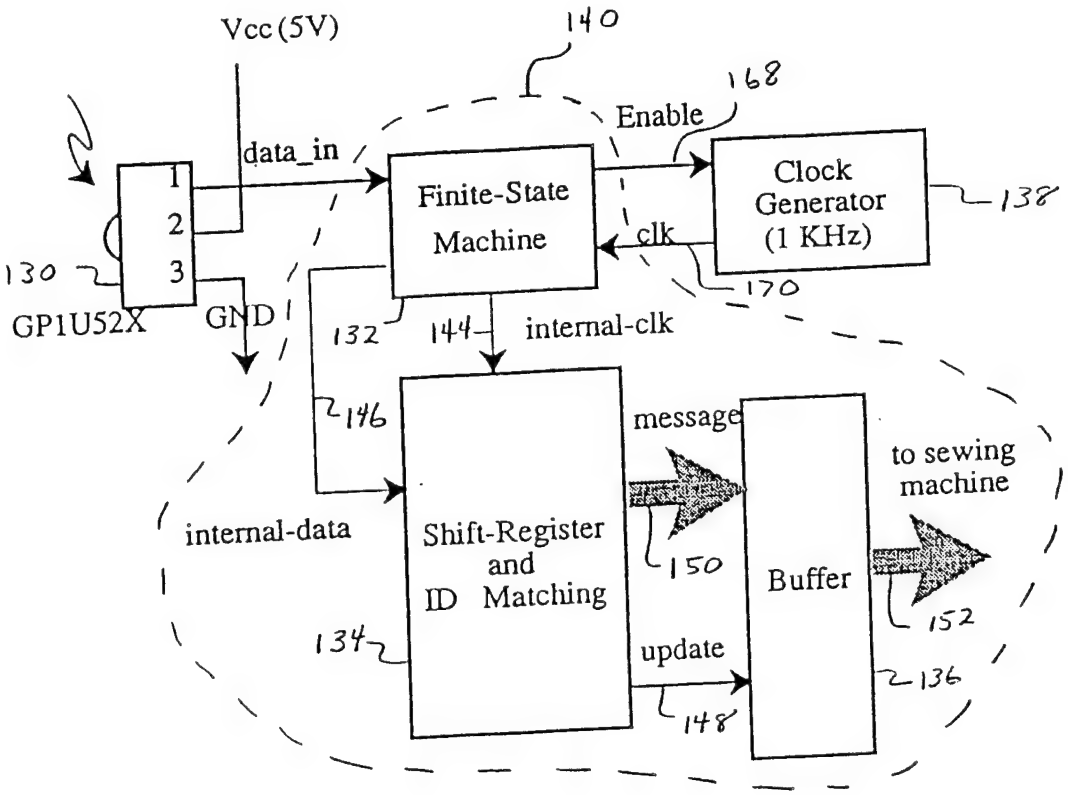

Vcc (5V)
140
168
Enable
data_in
Finite-State Machine
Clock Generator (1 KHz)
138
clk
170
130
1
2
3
GP1U52X
GND
132
144
internal-clk
146
message
to sewing machine
internal-data
Shift-Register and ID Matching
150
Buffer
152
134
update
136
148

FIG. 8a

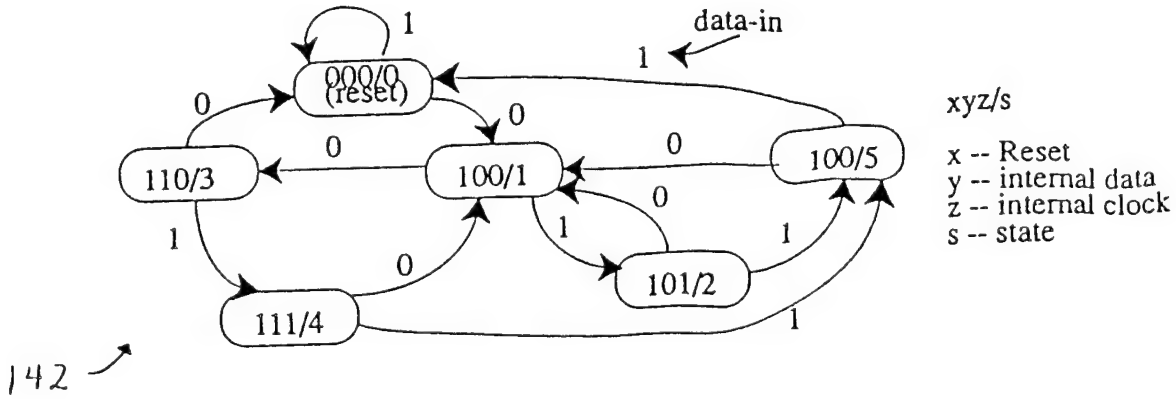

1
data-in
1
000/0 (reset)
0
0
0
0
0
110/3
100/1
100/5
1
0
1
1
0
101/2
111/4
1
xyz/s
x -- Reset
y -- internal data
z -- internal clock
s -- state
142

FIG. 8b

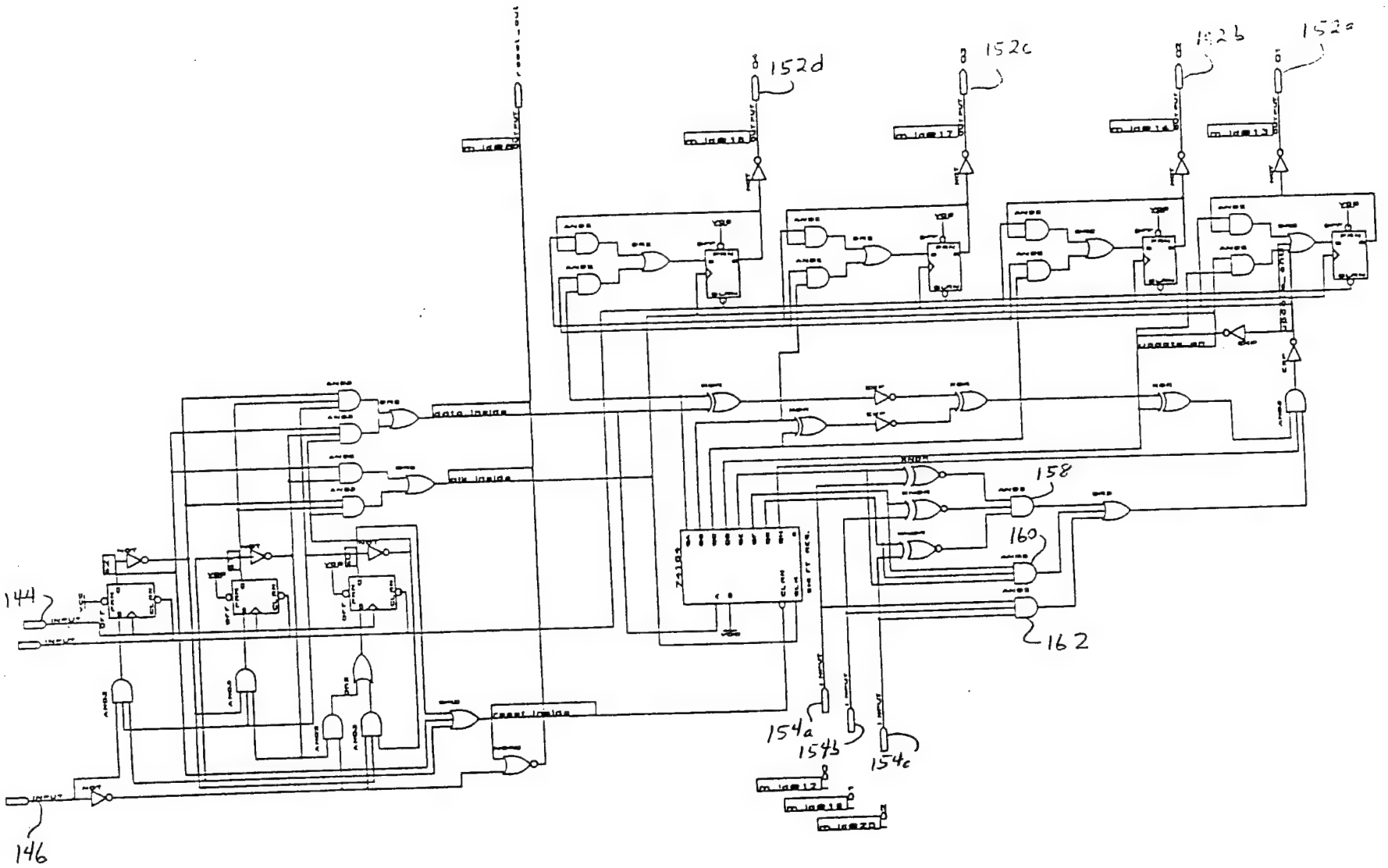
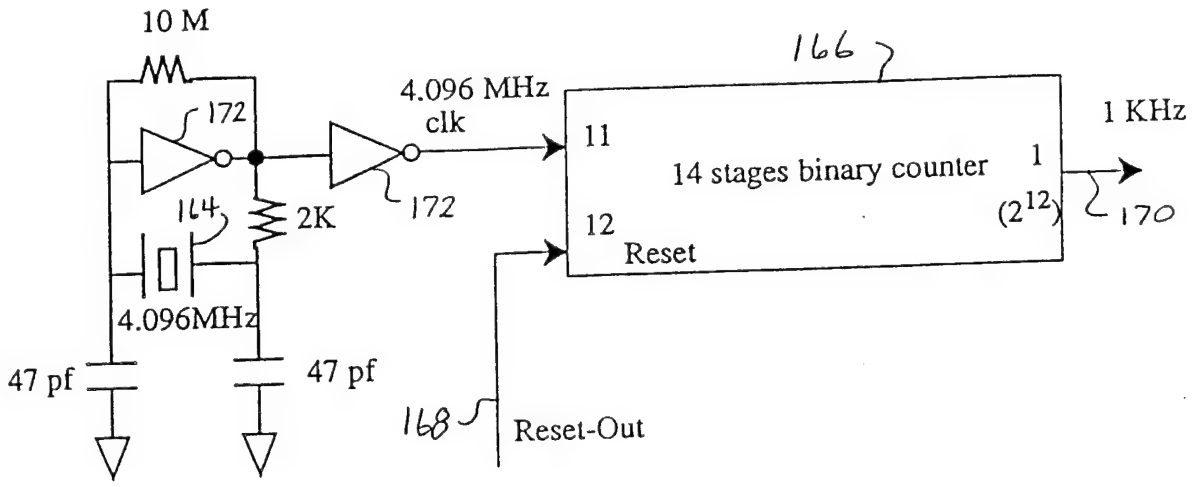


FIG. 8c



The Clock Generator

FIG. 8d

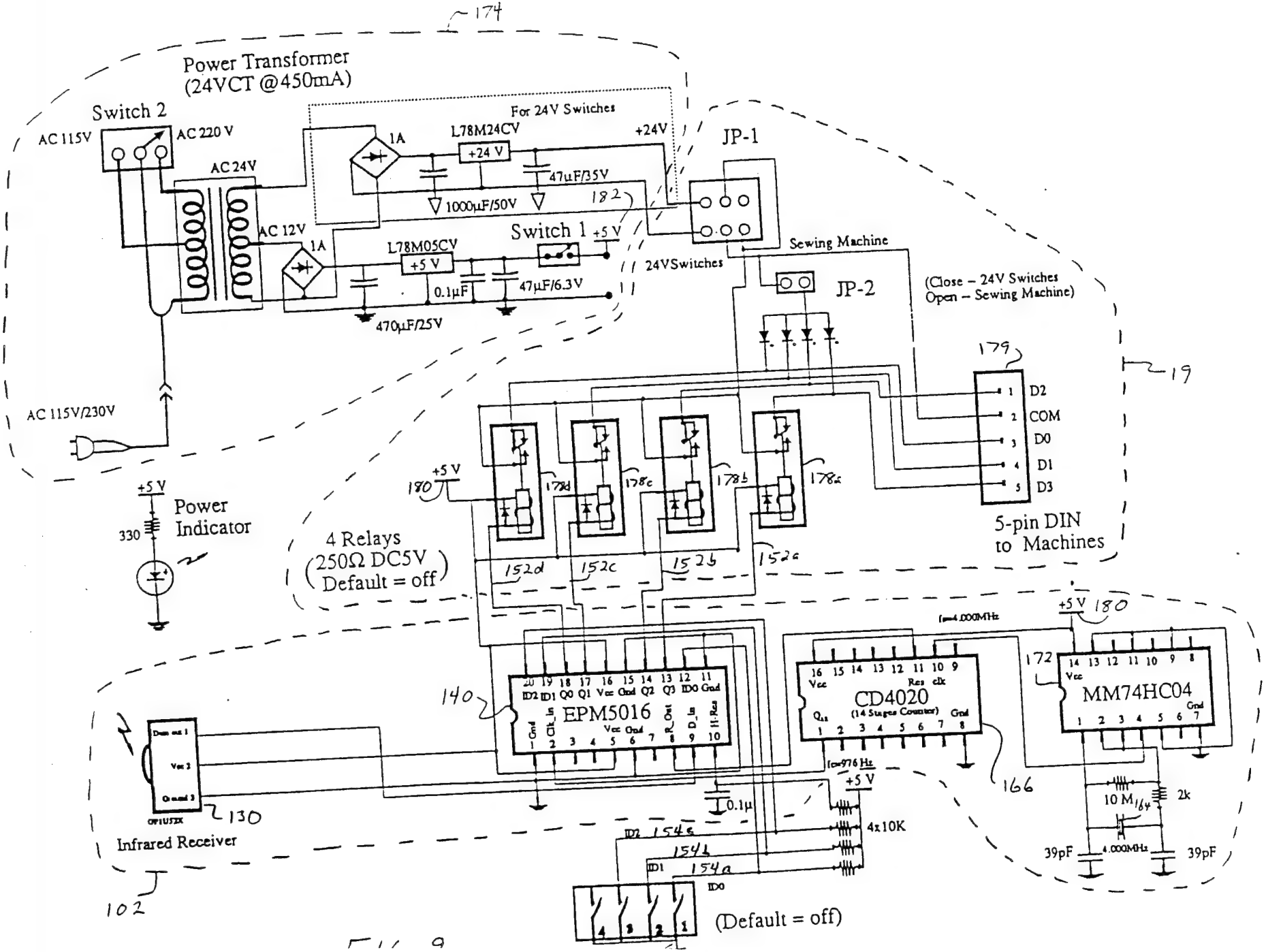

174
Power Transformer
(24VCT @450mA)
Switch 2
AC 115V
AC 220 V
AC 24V
AC 12V
1A
For 24V Switches
L78M24CV
+24 V
+24V
47uF/35V
1000µF/50V
182
JP-1
Switch 1
+5 V
L78M05CV
+5 V
0.1µF
47µF/6.3V
470µF/25V
24VSwitches
Sewing Machine
JP-2
(Close – 24V Switches
Open – Sewing Machine)
179
19
D2
COM
D0
D1
D3
5-pin DIN
to Machines
AC 115V/230V
+5 V
Power
Indicator
330
180
178d
178c
178b
178a
4 Relays
(250Ω DC5V
Default = off)
152d
152c
152b
152a
140
EPM5016
130
Infrared Receiver
102
+5 V
180
172
MM74HC04
CD4020
(14 Stages Counter)
166
f=976 Hz
0.1µ
4x10K
154c
154b
154a
ID2
ID1
ID0
(Default = off)
10 M
2k
39pF
39pF
4.000MHz

Fig. 9

Attorney Docket No.: CXU-153

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am an original, first, and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, to be submitted to the U.S. Patent and Trademark Office.

I acknowledge the duty to disclose all information known to me to be material to patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim the benefit under Title 35, United States Code Section 120 of any United States application(s) or PCT International Application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in such prior application(s) in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulation, Section 1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

Application Serial No. or PCT Application No. (and any assigned USSN)	U.S. or PCT Filing Date	Status -- Patented Pending, or Abandoned
08/155,100	11-19-93	Pending
07/763,347	09-20-91	Abandoned

POWER OF ATTORNEY: As a named Inventor, I hereby appoint the following attorney(s) to prosecute this application and transact

all business in the Patent and Trademark Office connected therewith.

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James M. Bagarazzi	Registration No. 29,609
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Mark C. Dukes	Registration No. 32,343
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(803) 271-1592
FAX (803) 233-7342

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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DUANPEI WU

Inventor's Signature _____ Date _____

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Citizenship: People's Republic of China

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Appendix C

Licensing Agreement

LICENSE AGREEMENT

1.0 Parties

The parties to this Agreement entered into this 11 th day of sept., 1992, are CLEMSON UNIVERSITY, a body politic and corporate under the laws of the State of South Carolina, whose address is 206 Sikes Hall, Clemson, South Carolina, hereinafter referred to as "LICENSOR," and EFKA of AMERICA, Inc., a legal entity organized under the laws of Georgia, whose U.S. mailing address is 3715 Northcrest Road, Suite 10, Atlanta, GA 30340, hereinafter referred to as "EFKA". EFKA should hereinafter be referred to as "LICENSEE."

2.0 Background

WHEREAS the following premises pertain to this Agreement.

2.1 LICENSOR owns, by assignment, the entire right, title and interest in and to inventive subject matter relating to an APPARATUS AND METHOD FOR VOICE CONTROLLED APPAREL MANUFACTURE AND APPLICATIONS THEREOF, hereinafter collectively referred to as "VCAM", which inventive subject matter is described in part in U.S. Patent Application No. WE WILL KEEP THIS CONFIDENTIAL UNTIL AGREEMENT IS READY TO BE SIGNED filed on WE WILL KEEP THIS CONFIDENTIAL UNTIL AGREEMENT IS READY TO BE SIGNED, 1991, entitled "Apparatus and Method for Voice Controlled Apparel Manufacture" in the name of John C. Peck et al, such patent application, all divisions and continuations of such U.S. patent application, the right to file foreign applications claiming priority based on such U.S. patent application, and all foreign patent applications which have or may be filed, including all divisions and

continuations of such foreign patent applications. Such inventive subject matter, original U.S. patent applications and continuations and division applications of same, if any, foreign patent applications, if any, continuation and division applications, if any, of foreign applications, KNOW-HOW defined below, any and all United States Patents covering such inventive subject matter, including but not limited to patents issuing from said U.S. application, including all reissues and extensions of any such U.S. patents that issue, and any foreign patents that issue from any foreign patent applications, including any extensions of any such foreign patents, are hereinafter referred to as LICENSOR'S PROPERTY RIGHTS.

2.2 LICENSOR owns the entire right, title and interest in and to further technical and confidential information relating to the construction and manufacture of VCAM and uses and processes employing same, such technical and confidential information being herein referred to as "KNOW-HOW."

2.3 LICENSEE wants an exclusive license to manufacture, use and sell VCAM within LICENSOR'S PROPERTY RIGHTS, but only in the field of control applications for sewing machines with electronically controlled motors, and not any other applications, for example not for cloth cutting machines or folding machines or packaging machines. LICENSOR agrees to discuss licensing of applications outside the licensed field with LICENSEE, prior to entering any license agreement with other companies, to determine possible interest of LICENSEE in the new applications. LICENSOR agrees to grant LICENSEE the right of first refusal to become LICENSEE for each new application.

2.4 A "Valid Patent Claim" means a claim contained in an unexpired patent or pending patent application, which claim either:

(a) has not been held unenforceable, unpatentable or invalid by a decision of a court or other governmental agency of competent jurisdiction, which

decision is unappealable or unappealed within the time allowed for appeal, or (b) has not been admitted to be invalid or unenforceable through reissue or disclaimer filed in the governmental agency of competent jurisdiction.

2.5 "Licensed Device" means any VCAM device, the manufacture, use or sale of which falls within the scope of a Valid Patent Claim, or which incorporates KNOW-HOW, or the manufacture, use or sale of which utilizes KNOW-HOW.

2.6 "Product" means any and all products which include a Licensed Device.

2.7 "Gross Sales Price" means the LICENSEE'S invoice price for a sold product or the total monies to be received as lease payments for a leased product.

2.8 "Subsidiary" means any corporation directly or indirectly owning, owned by, or under common ownership with the party in question to the extent of at least fifty percent (50%) of the voting shares, including directors' qualifying shares owned beneficially by such party, having the power to vote for directors.

3.0 License Grant

NOW, THEREFORE, for and in consideration of the premises set forth above and of the mutual covenants set forth below, it is hereby agreed as follows:

3.1 Contingent upon EFKA's continuing compliance with Sections 4.0, 9.0, and 16.0 of this Agreement, and subject to the provisions of Sections 4.0, 9.0, 16.0 and their respective Paragraphs, LICENSOR hereby grants to LICENSEE the exclusive license with power to grant sub-licenses to use and sell VCAM in accordance with that portion of LICENSOR'S PROPERTY RIGHTS that empowers the owner thereof to exclude all others from making, using or selling Products in the field of control applications for sewing machines with electronically controlled motors. LICENSOR hereby grants LICENSEE the right

of first refusal should LICENSEE wish to license VCAM technology in areas other than sewing machines with electronically controlled motors. Manufacturing rights for the Product are subject to restrictions applied by component suppliers of the Product.

3.2 Such portion of LICENSOR'S PROPERTY RIGHTS contingently conveyed in Paragraph 3.1 reverts to LICENSOR automatically upon EFKA's failure to comply with any provision of Sections 4.0, 9.0 and 16.0 and their respective Paragraphs, of this Agreement or upon termination of this Agreement in accordance with Section 9.0 and its Paragraphs.

3.3 The grant of Paragraph 3.1 under LICENSOR'S PROPERTY RIGHTS does not apply to any other fields of VCAM applications. For example, this grant does not apply to applications of VCAM in the fields of cloth cutting machines or folding machines or packaging machines, for which LICENSEE has right of first refusal.

3.4 The LICENSOR grants to the LICENSEE the right to use and protect a tradename and logo, with approval by the LICENSOR, for use in marketing the Product. The LICENSOR will not unreasonably withhold approval of such requests for tradename or logo use.

4.0 Royalty Payments

4.1 EFKA agrees to pay to LICENSOR a Royalty for each Product in the amount of the greater of fifty dollars ($50) or ten percent (10%) of the LICENSEE's Gross Sales Price to its customers, of each Product. Royalties shall not be paid on returned Products.

4.2 A Royalty accrues for each Product under this Agreement when it is shipped to a LICENSEE'S customer. LICENSEE pays such Royalty on each

Product sold by LICENSEE or subcontractor of LICENSEE, regardless of intended purpose or price.

4.3 Beginning with the date LICENSEE first offers units for sale, (herein termed the Contract Anniversary Date), if either:

- Royalties are paid on fewer than ten (10) Products sold worldwide hereunder during the first year, or

- Royalties are paid on fewer than one hundred (100) Products sold worldwide hereunder during the second year, or

- Royalties are paid fewer than five hundred (500) Products sold worldwide hereunder during the third year, or

- Royalties are paid fewer than five hundred (500) Products sold worldwide hereunder during the fourth year, or

- Royalties are paid fewer than five hundred (500) Products sold worldwide hereunder during each of the years after the fourth year or

-EFKA becomes a defendant or respondent in a bankruptcy proceeding, voluntarily or involuntarily, or becomes the subject of insolvency proceedings of any kind, including any compromise with or assignment for the benefit of creditors, or of any reorganization or liquidation proceedings, then LICENSOR has the right to convert the exclusive grant of Paragraph 3.1 into a non-exclusive grant by providing sixty (60) days written notice of such conversion to LICENSEE. Specifically, the conversion shall be from the present Paragraph 3.1 to the following substitution Paragraph 3.1:

> Contingent upon EFKA's continuing compliance with Sections 4.0, 9.0, and 16.0 of this Agreement, and subject to the provisions of Sections 4.0, 9.0, 16.0, and their respective Paragraphs, LICENSOR hereby covenants that LICENSOR shall not use LICENSOR'S PROPERTY RIGHTS to exclude LICENSEE from making, using or selling Products in the field of control applications for sewing machines with

electronically controlled motors. This promise does not apply to any other fields of VCAM applications. For example, this promise does not apply to applications of VCAM in the fields of cloth cutting machines or folding machines or packaging machines.

4.4 EFKA shall furnish to LICENSOR on or before the fifteenth day of each of January, April, July and October of each calendar year of this Agreement a **certified statement** showing the computation of Royalties for all Products manufactured and sold and/or leased hereunder during the immediate preceding three calendar month period, and at the time of furnishing said statement shall remit to LICENSOR the Royalties payable and **any supplement** thereto designated as Royalties (for the purpose of preventing exercise of LICENSOR's right under paragraph 4.3) as shown by such statement.

4.5 EFKA agrees to pay to LICENSOR a nonrefundable lump sum License Fee in the amount of ten thousand dollars ($10,000) on the Contract Anniversary Date as defined in paragraph 4.3. Within 30 days after LICENSOR submits statements to EFKA, EFKA shall reimburse LICENSOR for all fees and other expenses incurred by LICENSOR for pursuing and maintaining foreign patent applications pertaining to VCAM and incurred by LICENSOR as of the date of execution of this Agreement and thereafter. LICENSOR shall pursue foreign patent applications in countries identified by EFKA in a timely fashion, provided that EFKA reimburses LICENSOR for all fees and other expenses incurred by LICENSOR for pursuing and maintaining such foreign patent applications and patents within 30 days after LICENSOR submits to EFKA statements for such expenses. EFKA'S failure to reimburse LICENSOR for fees and other expenses pertaining to foreign patent applications and patents automatically excludes the corresponding applications and patents from LICENSOR'S PROPERTY RIGHTS, but does not remove the liability for payment of such fees. In carrying out the

reimbursement obligation of LICENSEE, LICENSEE agrees to pay LICENSOR'S designated patent attorneys directly for all fees and expenses incurred in pursuing and maintaining foreign patent applications pertaining to VCAM.

5.0 Recordkeeping

LICENSEE agrees to keep true, accurate and detailed records showing all information necessary for the computation of Royalties due hereunder. LICENSEE'S records pertinent to the Products under this Agreement shall be open to inspection by **a person(s)** as designated by LICENSOR and at LICENSOR'S expense at any reasonable time during ordinary business hours, but not more than once quarterly, for the purpose of verifying the computation and amount of Royalty due hereunder, and for no other purpose.

6.0 Status of Improvements

LICENSOR agrees to disclose in writing to LICENSEE, and LICENSEE agrees to disclose in writing to LICENSOR, within a reasonable time, all improvements in VCAM that it shall make or which shall come under its control. The disclosee party shall thereafter have Sixty (60) days to elect to include any such improvement under the present Agreement, and, if so elected, the said improvement shall become a part of this agreement at no increase in Royalty from LICENSEE. For any elected improvement that is deemed patentable by LICENSOR, LICENSOR agrees to promptly file an application for United States Letters Patent, and at the appropriate time file or assist in filing corresponding applications in such foreign countries as selected by LICENSEE. The cost of application and maintenance of all U.S. patents, including attorney fees, will be borne by LICENSOR. LICENSEE agrees to bear all the costs, including attorney

fees, associated with all foreign applications, prosecution of such applications, and maintenance of all such applications and patents which mature therefrom, in countries in which LICENSEE desires protection. Should LICENSEE develop the improvement, LICENSEE and LICENSOR agree to negotiate in good faith suitable compensation for LICENSEE on a case-by-case basis. Provided however, that should LICENSEE decide not to bear the costs related to any such application or patent, LICENSEE shall notify LICENSOR in adequate time to enable LICENSOR to pursue same, if LICENSOR so desires, at LICENSOR'S expense. Once LICENSOR undertakes responsibility under this Section 6.0 for the costs of such application(s)/patent(s), such application(s)/patents(s) shall thereafter be excluded from LICENSOR'S PROPERTY RIGHTS and LICENSEE shall have no rights in or to any such improvement(s), application(s) or patent(s), or any KNOW-HOW pertaining thereto.

7.0 Patent Marking

LICENSEE agrees to apply to all Products, a patent notice complying with 35 USC 287. The patent information to be used in such patent notice shall be subject to LICENSOR's prior written approval.

8.0 Third Party Infringement

Joint litigation for third party infringement in the U.S. shall be initiated only with the written consent of both parties. If one party declines to pursue such litigation, then the other party may choose to litigate independently. Costs associated with litigation shall be borne equally by both parties, in cases of joint litigation, or completely by the single party, in cases where only one party litigates. The monies or other consideration obtained from such third parties will be divided

equally among the litigating parties, in the case of joint litigation, or be the sole property of the single litigating party, in cases where only one party litigates. Litigation for third party infringement in foreign countries shall be pursued and funded entirely by LICENSEE and any consideration obtained from such litigation shall be the sole property of LICENSEE, with the exception of normal license fees associated with units sold by third parties related to the litigation. LICENSOR has no obligation to pay for or to give LICENSEE credit against Royalties for payment of, any and all expenses incurred by LICENSEE in pursuing and prosecuting controversies against third parties for infringing LICENSOR'S PROPERTY RIGHTS.

9.0 Term and Termination

9.1 This Agreement and the LICENSOR'S grant in paragraph 3.1 hereunder, unless sooner terminated as provided in this Agreement, continue from the Contract Anniversary Date (defined in paragraph 4.3) for a period of exactly four (4) years, and thereafter shall be extendable by EFKA in yearly increments upon giving written notice to LICENSOR no later than 30 days prior to the Contract Anniversary month and day of the year immediately preceeding the year of the desired extension.

9.2 EFKA has the right to terminate this Agreement after expiration of any patent included in LICENSOR'S PROPERTY RIGHTS. Such termination must follow a Thirty (30) day written notice of intent to terminate.

9.3 Clemson has the right to terminate this agreement if six months elapse after signing of this contract and EFKA has not yet offered units for sale (see Contract Anniversary Date as defined in paragraph 4.3).

9.4 Either party shall have the right, if it so elects, to terminate this

Agreement because of any breach or default of the other party in the performance of any promise or covenant required to be performed by it hereunder, provided that, the non-breaching party notify the party alleged to be in default in writing of such breach and the alleged breaching party shall fail to remedy such breach or default within Thirty (30) days of such notice. If either party waives its rights due to breach of any provision of this Agreement, such waiver shall not be construed as a continuing waiver of other breaches of the same or other provisions. Termination of this Agreement for any reason does not relieve EFKA of its obligation to pay any Royalties which have accrued by the date of such termination or which may accrue thereafter. Such termination by either party because of a specified breach shall not operate as a waiver of any breach by the other party of any of its covenants hereunder, and each party shall have the right to any remedies otherwise available to it for damages caused by such breach.

10.0 Integrated and Severable

10.1 This Agreement constitutes the entire understanding of the parties and cannot be changed orally, but only by an instrument in writing signed by the party against whom enforcement of any waiver, change, modification or discharge is sought. This Agreement supersedes all pre-existing agreements between the parties respecting the subject matter of this Agreement. Any representation, promise, or condition in connection with such subject matter which is not incorporated in this Agreement is not binding upon either party.

10.2 Any provision of this Agreement held invalid or unenforceable by a court of competent jurisdiction shall be severable from the remaining provisions of this Agreement so long as such severance does not destroy the underlying premises and purposes of this Agreement.

any kind, either express or implied, or assumes any responsibilities whatever with respect to use, sale, or other disposition by the other party or its vendees or transferees of products incorporating or made by use of LICENSOR'S PROPERTY RIGHTS.

13.0 Notices

Communications and notices by either party to the other in accordance with any of the provisions of this Agreement must be in writing and sent by registered mail to the respective addresses:

LICENSOR Office of the Vice President
for Business & Finance
206 Sikes Hall
Clemson University
Clemson, South Carolina 29634-5301
Office Number: (803)-656-2420
FAX Number: (803) 656-2008

LICENSEE Vice President
Efka of America, Inc.
3715 Northcrest Road
Suite 10
Atlanta, Georgia 30340
Office Number: (404)457-7006
FAX Number: (404)458-3899

or to either party at such other address as such party may hereafter designate in writing to the other.

14.0 Confidentiality

Each party undertakes to keep secret and confidential and not to disclose to any third party, except as it is necessary in carrying out the purposes of this Agreement, during the term of this Agreement and for a period of **two (2)** years thereafter, any information, data or know-how disclosed to it and identified as "confidential" in writing by the other party except:

(1) information, data and know-how which at the time of disclosure is in the public domain or publicly known or available;

(2) information, data or know-how which, after disclosure, becomes part of the public domain or publicly known or available by publication or otherwise, except by breach of this Agreement by the receiving party;

(3) information, data or know-how which the receiving party can establish by competent proof was in its possession at the time of disclosure by the other party;

(4) information, data and know-how which the receiver receives from a third party; provided, however, that such information was not obtained by said third party from the other party; and

(5) information, data and know-how which the receiver derives independently of such disclosure.

15.0 Applicable Law and Personal Jurisdiction Waiver

15.1 This Agreement shall be construed in accordance with the laws of the State of South Carolina.

15.2 As to disputes arising between LICENSOR and LICENSEE and concerning any and all aspects of this Agreement, LICENSEE hereby agrees that

personal jurisdiction and venue as to LICENSEE are proper in the United States District Court in Greenville, South Carolina and the South Carolina State Courts in Greenville, South Carolina.

16.0 Compliance with Export Laws

Regulations of the United States Department of Commerce (USDC) prohibit, except under a special validated license, the exportation from the United States of technical data relating to certain commodities unless the exporter has received certain written assurances from the foreign importer. LICENSEE shall obtain all necessary licenses required for LICENSOR to lawfully convey KNOW-HOW to LICENSEE. Moreover, so that LICENSOR can fulfill the requirements of these USDC® regulations, LICENSEE hereby gives its assurance that LICENSEE will not, without prior authorization of the United States Office of Export Administration, knowingly:

16.1 With respect to any technical data received from LICENSOR relating to commodities identified by the symbol "W" in the corresponding entry of the Export Administration Regulations ("EAR") Commodity Control List (15 C.F.R. _ 799.1) under the paragraph "Validated License Required" and originating in the United States, reexport such technical data, directly or indirectly, to Country Group P, Q, S, W, Y, or Z as defined in the EAR (15 C.F.R. _ 370, Supplement 1) or to Afghanistan without prior authorization from the Office of Export Administration, United States Department of Commerce. LICENSEE will not knowingly export, directly or indirectly, any "direct product" of such technical data to Country Group Z as defined in the EAR without prior authorization from

the Office of Export Administration, United States Department of Commerce; or

16.2 With respect to the "direct products" as defined in the EAR of any technical data received from LICENSOR and originating in the United States, which "direct products" are identified by the code letter "A" following the Export Commodity Control Number for those "direct products" in the EAR Commodity Control List, export, directly or indirectly, any such "direct products" of such technical data to Country Groups P, Q, S, W, or Y, as defined in the EAR, or Afghanistan, without prior authorization from the Office of Export Administration, United States Department of Commerce.

17.0 Execution

IN WITNESS WHEREOF, the parties hereto have caused this instrument to be executed below by the signatures of their duly authorized representatives.

CLEMSON UNIVERSITY
LICENSOR

By: [signature], 3/11/93
David R. Larson, Vice Pres.
for Business & Finance

ATTEST:

EFKA of AMERICA
LICENSEE

BY: _____
, Vice Pres.
EFKA of AMERICA

ATTEST:

A:\CXU153-A.AGR